E-300-101

PUBLIC SAFETY-FIRE TECHNOLOGY

Technical Report No. 1

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Project E-300-101

High Temperature Materials Division
Engineering Experiment Station
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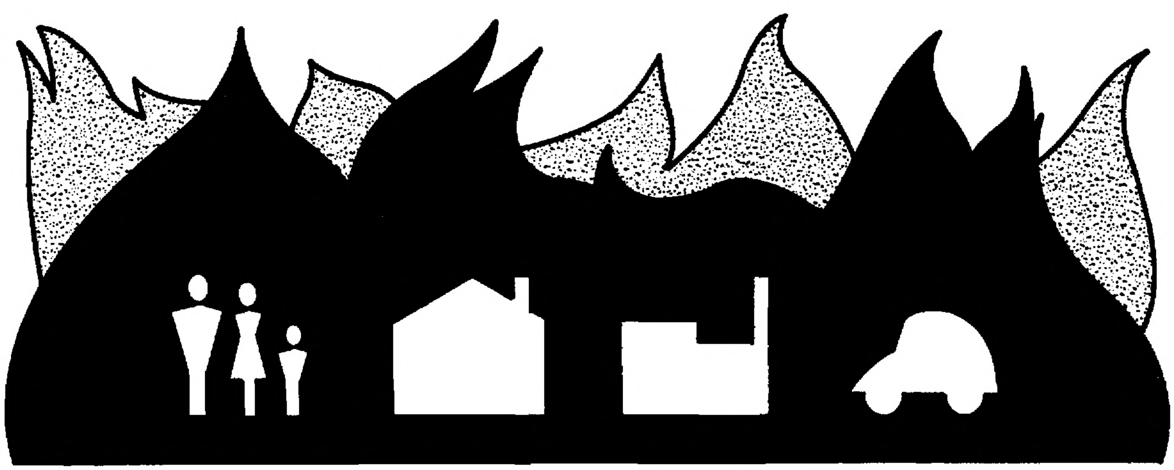

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TABLE OF CONTENTS

I. INTRODUCTION

The personnel of the High Temperature Materials Division (HTMD) of the Engineering Experiment Station at the Georgia Institute of Technology have years of experience in physical, structural, and thermal analyses of organic and inorganic materials. This experience includes experimental as well as theoretical work in many diverse areas.

During the last year and a half, the Division developed an interest in, began developing a background, and initiated work in fire technology. The particular area of research concerned the evaluation of "poke-thru" systems mounted in concrete slabs. "Poke-thru" is the name used by the building trade to describe the floor-mounted convenience outlets for electrical power and communication systems. A detailed account of this research is given in Reference 31 listed on page 24.

The involvement of HTMD personnel with the poke-thru work mentioned in the previous paragraph led to an interest in the general area of fire technology. As a result, a literature study was undertaken to determine potential areas of research suited to the unique capabilities of HTMD. This literature survey is presented in the following section, BACKGROUND. Later sections include a description of facilities and personnel, experience in fire technology, and an assessment of critical needs in fire technology.

II. BACKGROUND

The literature survey presented in this section is intended to present an overview of the current state of fire technology with particular emphasis on public safety. Recently national and worldwide concern has intensified in regard to potential fire hazards. Some of the new construction techniques and materials used in mobile homes, homes, multiple occupancy dwellings, and high rise complexes have resulted in many disastrous fires.

A. Fire Hazards

In a country which has seen great technological achievements in history, the United States attained the dubious distinction of leading all the major countries of the world in per capita deaths and property loss from fire. The American annual losses attributed to fire are 12,000 persons killed, 100,000 persons injured. Within the next hour there is a statistical likelihood that more than $300,000 in property will be lost, thirty-four people will be injured, and at least one life will be lost. An estimated 11.4 billion dollars is wasted yearly in property losses, hospitalization costs, fire department maintenance, and loss of productivity. An additional 300,000 people suffer physical and physcological injuries that require extensive hospital treatment, and some never recover 1-4/.*

A fire at the Harmer House in Marietta, Ohio, became a disaster when thirty-two people perished in the flames of the single story nursing home 5/. Rapid news coverage of the fire focused national attention on the need for investigations into the causes of major fires. Suddenly the public was not only concerned with the source of the flame, but also wanted to know by what

*The numbers refer to the list of references on page 23.

mechanism and material flammability was responsible for such a fire to claim so many victims.

Other more recent fires in high-rise structures received extensive coverage on television and in newspapers, and continued to stimulate public interest in the hazard of fires. On November 29, 1972, in New Orleans, Louisiana, a fire on the fifteenth floor of the Rault Center was responsible for the death of six persons. The sixteen-story, concrete building which was open for occupancy in 1968 was of a fire-resistive construction design, but interior design, lack of a sprinkler system, no fire alarm, and furnishings together with a broken window at the end of a corridor were all factors which contributed to the six deaths. But it was found that the concrete structure and gypsumboard wall partitions performed as designed and withstood the effects of the fire 6/.

The next day on November 30, 1972, a fire which originated from an upholstered chair was discovered on the seventh floor of the Baptist Towers Home for Senior Citizens in Atlanta, Georgia. When the occupant left her apartment to escape the flames and smoke, the door was left open and the fire moved across the carpet to the corridor. Other apartments were exposed to the intensified fire by the air supply make-up to the corridor. Carpeting with high fire hazard characteristics was used to cover the corridor floor and contributed to the flame spread. Toxic gas and smoke were also generated in the corridor. The end result was the death of ten people attributed to burns or gas and smoke inhalation. Subsequent tests indicated that the carpet with an integral foam rubber backing did not have sufficient fire spread resistance, and would propagate a flame when exposed to an ignition source of high enough intensity 7/.

On November 15, 1972, at the John Hancock Center in Chicago, Illinois, a fire erupted as a result of careless burning of cash register tapes in a coctail lounge on the ninety-sixth floor. The building was designed for fire resistiveness; it was of steel construction with a sprayed-on asbestos material. The ninety-sixth floor was protected by an automatic sprinkler system in the kitchen and a heat-sensitive fire detection system in the lounge. Although the floor was covered with a nylon/wool carpet, the covering did not contribute to flame spread. Very little combustible material was used in the interior decoration and furnishings on the ninety-seventh floor helped to prevent extensive damage. No causalties were reported 8/.

Ten persons died in a boarding home fire in Pleasantville, New Jersey, on January 29, 1973. The structure was of wood frame construction with non-firestopped walls. Plywood paneling had been used extensively in renovations through the years. A fire detection system with fixed-temperature detectors and combination smoke and heat detection devices had been installed with communication to the local volunteer fire department. A stand-by power supply was provided for the detection systems. An incendiary fire started in a linen closet, moved along the wooden floors and wall paneling upstairs to the second floor by chimney effects of an open door and broken window. Before the fire was brought under control, ten of the eighteen people in the building were dead. It was pointed out afterwards that several important factors contributed to the results of the disaster: (1) communication with the fire department did not function, (2) an inadequate water supply, (3) poorly performed fire drills, and (4) the source of fuel, the plywood paneling 9/.

A fire in a cabaret at Osaka, Japan, on May 13, 1972, grimly demonstrated the deadly effects of poor construction design in fire spread resistance and poor or no escape planning. The fire originated from a match dropped onto synthetic dress fabrics. Smoke, toxic gases, and the flames moved through four open stairways from the third floor to the cabaret on the seventh floor. The exit sign for the one enclosed stairway was hidden behind ceiling decorations. Also, only the basement and first floor were provided with a sprinkler system. When the fire was finally contained, 119 persons had either jumped to their death, or were crushed to death, or had died from suffocation and 69 others were injured in the fire-resistive building. The numbers could have been smaller had the employees drilled on the use of the available canvas escape chutes 10/.

The fire at a residence in Suisin, California, provided a grim example of the interest and concern that the public has concerning carpeting and other floor covering as a prime source of ignition or fuel involved in the spread of a fire. Flames from paper burning in the fireplace spread to the carpet. As the resident applied water to the fire, flashover spread the flames across the carpet and the entire living room was consumed 11/. Fortunately, the resident escaped.

A small fire was found in acloset on the seventh story of the fire-resistive Imperial Apartments in Nashville, Tennessee. On leaving for assistance, the occupant left the door open and the corridor was exposed to fire and smoke from the apartment. An open stairway door fed air to the flames, the carpet and pad quickly propagated the flame over the entire six foot wide corridor. One death and one injury resulted. Samples of the carpet could readily be ignited with a match and thick black smoke was emitted 12/.

The Federal Trade Commission recently announced disclaimers about the self-extinguishing characteristics of polyurethane foam, a material which has been used in construction, furniture, and electrical and plumbing fixtures 13/. The cellular plastic was suspected in the astronaut deaths in Apollo I, and the 145 deaths at the Cinq Sept Dance Hall, Grenoble, France.

The concern about fire hazard has also included the potential fire source of more personal items (particularly, children's sleepwear); and, in California cooperation between industry and fire control officials is moving forward in investigations and in establishing minimum requirements on the degree of flammability of disposable fabrics which are in common use in hospitals 14/.

B. Fire Tests of Materials and Construction

The specifications of architects, interior designers, and the construction industry have to meet and satisfy the requirements of local building codes and federal legislation for combustibility of materials, the fire endurance of structural elements, and the falmmability of interior finishes. Investigators have endeavored to define, find, and establish adequate laboratory techniques to evaluate these materials. It is also necessary to interpret and correlate the results of controlled laboratory experiments with the actual results which would be found in a real fire. Herein lies the problem, since each real fire is unique. Minor differences in construction, interior design, interior construction, furnishings, and location could contribute variations in the fire endurance as specified by a building code and these variations may not be considered in present test methods. Carlson suggested that building codes should reflect three classifications of materials and assembly of materials: (1) the classification of noncombustible materials, (2) the fire endurance rating of materials and assembly of materials, and (3) the test methods used in determining the surface flammability of interior finishes. He stressed the need for better test procedures with more comprehensive reporting and classification of the test data A hazard classification should be reported with emphasis on the end application of the materials 15/. Rarig points out that materials are not dangerous and do not create fire hazards. Therefore, laboratory analysis of these materials is not an assessment of the potential fire hazard. The end use of the material presents the hazard, and it is this hazard that must be characterized. Laboratory tests are useful for basic information to tell about the material's development, but "...that our truly useful performance standards are based on tests that evaluate the end uses of materials or assemblies" 16/.

Yuill divided fire tests into two test classes: (1) basic properties of the materials, and (2) the reaction of the materials and combination of these materials in fire situations. He stressed the need for correlation between small-scale and large-scale fire tests, but was not optimistic about such a possibility. The danger of small-scale tests was "...manufacturers will 'shop around' for the fire test procedure that will show their particular material to the best advantage" 17/. Bletzacker wrote that laboratory tests were a simplification and idealization of actual conditions which is particularly true in fire tests. Economics and feasibility preclude the fire testing of full scale replicas; therefore, investigators must adapt and provide small scale quanitative test procedures which specifically state the limitations of these tests, but which still afford a correlation to actual fire test when utilized correctly 18/. Unless such tests are devised and correctly utilized the terrible prediction of Davis might occur: "Unfortunately, an actual fire may be the only test of the adequacy of protection provided. Such a test is too awful to contemplate" 19/.

Foster 20/, Gustaferro and Abrams 21/, and others have performed fire endurance tests on large sampled building elements by the standard test procedure ASTM E-119. The test specification is the result of the available information on typical fire prediction, and is considered the test method to use for fire endurance measurement and rating of building materials and construction. Foster performed fire tests at Ohio State University on ceramic tile walls which were subjected to various loads and subsequently water quenched by a fire hose. The work of Gustaferro and Abrams was of particular interest. In addition to the evaluation of concrete two-way floor joints, an attempt was made to correlate the results with scaled-down fire tests of laboratory size. Using the same concrete mixes and cures, a significant difference in the observed fire ratings were observed. On full-scale slabs, it was assumed that the heat sink effect of the joists and the moisture in them produced the difference.

Harmathy has pointed out that variables in element design can affect the fire endurance rating. In the ten rules he had established for fire endurance rating, rules seven and eight could account for the discrepancy. Seven states that "The fire endurance of asymmetrical construction depends on the direction of heat flow," and eight states that "The presence of moisture if it does not result in explosive spalling, increases the fire endurance" 23/. Using ASTM E-119, he experimentally demonstrated that a variation in moisture content and the absorption of heat associated with dehydration reactions of brick and concrete elements were factors in the measurement of fire endurance 24/. Latent heat effects improved the performance of concrete for fire endurance. This work enabled Harmathy and Allen to analyze systematically the thermal effect on masonry concretes and to provide mathematical prediction of the fire endurance of this construction material 25,26/. Although the results are still preliminary laboratory conclusions, they still represent a useful knowledge of the response of materials to fire. Also, it was found that spalling of concrete in fires was not the result of the crystalline conversion of quartz but of high moisture content.

Abrams and Gustaferro 27/ and Gibbons 28/ also studied the factors which influenced the fire endurance of concrete. Their work emphasized the need for investigation of the individual components of concrete construction and their relation to fire endurance. Gustaferro summarized the work of the Portland Cement Association on the fire resistance of concrete. The design and restraint of a concrete slab could produce a fire endurance failure through thermal expansion in localized fires unless factors that effect the heat transmission are considered. The factors affecting the transmission of heat were thickness of the concrete, type of aggregate, and moisture condition of the concrete. He noted that artificially dried concrete slabs had lower fire endurance.

Gustaferro investigated the thermal effect on prestressed and reinforced concrete members when subjected to fire endurance tests, and found that the presence of restraint was a significant factor and could increase the fire endurance 29/.

Abrams and Gustaferro conducted further studies of fire endurance by the inclusion of poke-thru fittings and their effect on the fire rating on concrete by both laboratory-scale version of ASTM E-119 and the prescribed ASTM procedure for concrete slabs. Their conclusions recommended design changes in the poke-thru fitting assembly to eliminate the decrease in the fire rating of the concrete slab by the use of such items. A comparison of large-scale and small-scale tests indicated relatively good agreement, within 15 percent, in the fire endurance of the concrete slabs (there was a difference in slab thickness) 30/.

Poulos and Sales measured the fire endurance of specific poke-thru systems mounted in a reported two hour fire-rated concrete slab. They utilized small-scale fire tests and found that the fire endurance of the poke-thru assemblies was influenced by the hole through the slab; by the use of size, and type of metal shield over the wire; and by inorganic, fire-resistant coatings on metallic shields 31/.

Cartal pointed out that use of the convenience outlets should be constructed so as to neither effect the fire rating of the wall partition, ceiling, or floor in which it was installed nor cause the spread of fire becuase of the hole it had caused. He asked the same question that has been used by rating bureau inspectors: "Has the fire rating of this floor been destroyed or is it still 'substantially equivalent' to its original rating?" He also warned of the indiscriminate multiple use of such installations 32/. Shull warns that fire and smoke can spread through any opening in a structure, in his discussion on high-rise fire control 33/.

C. Fire Tests of Sub-Assemblies

The National Bureau of Standards (NBS) designed a corridor fire program to investigate the complex interacting thermal and fluid flow phenomena in a dynamic corridor fire. NBS also studied the contribution of interior finish materials, ceiling, and floor as well as the interior floor coverings. The corridor is 30 feet long by 6 feet 8 inches to 9 feet 3 inches high by a variable width of 6 to 12 feet. It is equipped with a forced air draft supply and instrumentation to study the corridor fire as a function of air flow and heat transfer by radiation, convection, and conduction. The fuel supply is located in a burn room to one side and consists of four wood cribs. The energy release rate from the cribs can reach a maximum of 80,000 Btu/min or a fire load of 2.7 pounds per square foot of burn room floor area 34,35/. Qualitative photographic description of the rapid propagation of a flame by the carpets can be obtained with these fire tests. NBS reported that when the radiant and convective energy reached a critical level, the carpets would ignite spontaneously and then burn vigorously until "flameover" was observed throughout the corridor. Therefore, the measurement of the critical energy to produce flame spread was suggested in addition to the more conventional approach to flammability testing 36/.

Interrelated with the corridor fire program was the work of Pryor on full-scale fire tests. This investigation involved possible reduction in the life hazard in structural fires through use of composite wall materials. The interest was generated by fatal fires in the California area which involved plywood finished interiors. Because of the lack of adequate information building specifications were established to reduce the fire hazard from these interiors. The results of the fire tests, correlated with the ASTM E84 test for surface burning characteristics, did not indicate any significant difference in a plywood or plywood composite interior but did find that doors were important to retard flame spread. Also, it was concluded that the use and position of interior furnishing should be controlled, which seems to be supported by the results of the fire in Pleasantville, New Jersey 37/.

Composite roof structures were studied by Kirk and the results demonstrated the value of additions of non-combustible fire barriers next to standard roofing materials. Gypsumboard effectively retarded the burn through of roof membranes in full-scale fire tests in frame structure houses. Further investigation of actual fires in the California area indicated that this material did afford thermal protection to wooden structural members 38/. The difference in the results of Pryor and Kirk points out that test procedure and test environment can produce seemly conflicting but valid conclusions. When fire test data is to be analyzed, the observation of Levy should be considered: "There is no such thing as a standard fire or standard test procedure, since they may range in scope from applying candle flames for 15 seconds to burning down obsolete buildings 39/.

Hilado 40-42/ and Way 42/ focused their investigations on the thermal insulation systems and the tendency of these materials to be the first that are subjected to fire. In their evaluation, the criteria specified that the thermal insulation should present no significant fire hazard. Their conclusions emphasized the importance of proper thermal insulation design. Again, seemingly contradictory evidence was presented about the fire hazard of cellular polyurethane. Used as thermal insulation in a properly designed system the material was not a fire hazard because of its tendency to char 42/. Yet under certain defined test procedures, polyurethane foam could be ignited with subsequent interpretation of the data indicating that the material was a fire hazard. Two statements related to the work were significant: (1) "No single flammability tests, and perhaps no combination of a limited number of tests, can predict behavior under all possible fire exposure conditions," and (2) "The marketing man's problem, however, is relatively easy to solve;

he either offers a product that is superior according to the existing acceptance test, or he promotes acceptance of a test that shows his product to be superior 40,41/. This has happened with polyurethane foam 13/.

D. Legislation and the Fire Hazard

The Flammable Fabrics Act of 1967 was on extension of legislation to protect the public welfare by the development of flammability standards for wearing apparel and interior furnishings. Definitions and procedures for the development of flammability standards were established. Active participation by anyone outside of the Department of Commerce, which was to be the enforcement agency, was encouraged 43,44/. After due notice of a proposed standard with invitations for comment from all interested persons 45/, two standards for rugs and small carpets and rugs, DOC FF 1-70 and DOC FF 2-70 were submitted and enacted into law 46,47/. The usual policy statements were issued 48/, and then the rules and regulations were defined 49/. Even though the "pill test," generic name for the two standards with ignition by a methenamine tablet, received the usual extensions and amendment during the 5 year interval 50-53/, enforcement of the act became effective and several orders were issued for firms to cease and desist from the sale or importation of carpets found to be hazardous 54,55/.

The test procedures for both standards are identical. A hollow cube made of non-combustible material such as cement asbestos board is the test chamber with 12 inch dimensions along the sides. A nine inch square of material is placed in the bottom of the chamber. The material is covered by a flattening frame which has an eight inch diameter hole in its center. A number 1588 methenamine timed burning tablet is placed in the center of the hole and ignited by a suitable source. The test is continued until all flaming and smoldering has ceased. If the charred area does not extend to within one inch of the edge of the hole in the frame for at least seven of eight samples, the materials meet the standard. Small carpets and rugs failing to pass the standards must have suitable warning labels attached.

Since the inception of DOC FF 1-70 and DOC FF 2-70, nearly one hundred companies had been cited for failure of their product to pass the pill test. Although the carpet industry recognized the need for flammability standards and cooperated in the standards development program, the industry "...had fell victim to the statistics of the situation." When the standard was adapted, it was recognized that an allowage should be made for imperfection 56/. For this reason the two flammability standards were revised when the Department of Commerce recognized the need for sampling plans 43,44,51,52/. The government and industry also recognized that the test was not infallible; for example, subsequent test of the carpet used in the Harmer House passed the pill test 5,57/.

The new Federal standards extended to children's sleepwear and mattresses. It was found that the incidence of fabric ignition of sleepwear for children age 6 to 12 was nearly twice the frequency expected from the age group representation. Therefore, a standard, DOC FF 3-71, was established for children's sleepwear in sizes 0-6X; and a standard was proposed, DOC PFF 5-73, for sizes 7-14. Minor differences exist in the test procedures and in the method for sample conditioning for the two standards. The test for flammability was simple, but set to rigid specifications for sampling, char measurement, and disposition of reflection 58,59/. This test was criticized because it might not produce inter-laboratory test repeatability because of the sampling method 60,61/. The National Bureau of Standards conducted statistical analysis of inter-laboratory flammability tests with sixteen participating laboratories. The analysis concluded that no gross differences in reproducibility were obtained using the flammability standard 62/.

The flammability standard for mattresses, DOC FF 4-72, was based on what was considered the primary source of ignition, a cigarette, which was the largest cause of single fatality fire involving bedding 63-65/. This standard was also the result of government and industry colaboration and was considered reasonable. Although utilization of the standard by the manufacturer of mattresses would probably result in increased production costs passed on to the consumer, the standard itself would protect the public welfare against fires and protect industry from criminal penalties and other enforcement provision 66/.

Once Motor Vehicle Safety Standard No. 302 became effective, the plastics industry took a positive attitude toward the flammability standards imposed for motor vehicle interiors. After an identification of the applications and types of materials used, the industry concentrated on means to impart the necessary fire retardance to these materials which would conform or surpass the standard's requirements 67-69/.

E. Research and Laboratory Testing

Wulff, et al., systematically analyzed the quanitative thermal properties of fabrics selected by the Government-Industry Research Committee on Fabric Flammability. The work was an experimental and analytical program to demonstrate that predictions exist between fabric ignition times as a function of exposure parameters and fabric properties. It was maintained that flammability standards should not be based on a particular property or one response to a particular set of circumstances but rather to logical, experimentally verified connection of properties and statistically relevant material ignition conditions. To accomplish this verification, the program was a study of fabric properties, heat sources, process parameters, and ignition criteria 70/.

Belason, et al., utilized the experience obtained in the design of thermal protection systems for spacecraft to design materials for fire protection 71/. A test facility was designed to permit evaluation of the one dimensional response of a material in a real fire environment. Critical in the design was a reduction of cost for the fire environment and a closely controlled, reproducible, calibrated and programmed fire environment. Thus far, studies have been conducted on time temperature response of materials, ignition response time, and analysis of combustion products of materials.

Kuchta, et al., studied the flammability of fabrics and other materials in oxygen-enriched atmospheres. The seriousness of fire in this environment was emphasized by the tragedies which occurred in an Apollo space capsule and a space environment simulator. Autoignition temperature decreased, flame spread hazard was greater, and flame spread rate increased for various angles for oxygen content from 42 percent and 100 percent. The atmosphere can also lower the ignition temperature of flame-retardant treated fabric over a comparable plain fabric 72,73/.

Levy simplified the 25 foot ASTM tunnel test and reduced the overall size to a more convenient laboratory configuration. The unit was calibrated with asbestos-cement and red oak as designated by ASTM. Correlation of flame-spread ratings for twenty-one materials indicated very good agreement with the full-size tunnel test for materials with a rating up to 150 74/.

Gustaferro and Abrams reduced the physical size requirements of ASTM E-119 to more practical dimensions for testing sub-assemblies in concrete slabs 30/.

Miller, et. al., experimented with oxygen depletion leading to flame extinction even in large volumes of air because convection was only partically effective in supplying air to the flame and the removal of combustion and pyrolysis products. They devised a technique to measure and extrapolate linear burning rates with a flammability analyze. Oxygen index values for directions of burning were obtained for various materials. It was found that all the tested materials, except a special nylon, were capable of upward burning in air 75/.

Chouinard, et. al., constructed an instrumented mannequin to measure heat transfer from garments after ignition by a flame source. They found that the burning characteristics of wool produced low heat transfer and that the melt-drip phenomenon of polyester and nylon resulted in slow burning rates and little heat transfer. Possible physiological effects were measured using data from the literature and pathological studies performed on porcine epidermis 76/.

Sanders developed a small-scale burning test for shag carpets which would correlate the tendency of a flame to propagate through the pile of a shag rug. Using carpets which had been tested by the federal flammability standards, he measured a pile burn index. He obtained correlation with rugs that either passed or failed the standard. The value of his test was a study of the effect of process chemicals and aging on pile carpets 77/.

III. FACILITIES AND EQUIPMENT

Facilities are available at Georgia Tech for research in virtually all phases of science and engineering. In addition to many general laboratories with standard equipment, several major research facilities have been established and still others are currently under development. Some of the facilities in the High Temperature Materials Division and the Micromeritics laboratories are discussed below.

Facilities exist for slip-casting, molding, and firing ceramics in electric and gas kilns at temperatures up to 4000° F. The largest known monolithic ceramic radome (two feet base diameter by four feet in length) was fabricated at Georgia Tech. A filament winding machine capable of winding shapes up to three feet in diameter and six feet in length is used for the development of high temperature filament wound structures, as well as the conventional fiberglass systems. A spray dryer is used to process fine particles in ceramic precursors. An isostatic press with a 6 inch diameter by 23 inch depth cavity is in operation. The laboratories cover 15,000 square feet and employ 13 engineers and scientists, with 5 technicians and numerous student assistants (graduate and undergraduate). An arc plasma jet having an operating range of 10,000° to 20,000° F is available. In addition, plasma jet and oxyacetylene flame-spray equipment are available to coat various metals and oxides onto ceramics or metals. Small gaseous and solid propellant rocket motors and a plasma jet wind tunnel are used in studies of thermal and erosion effects of high temperature, high velocity gases on materials. Analytical instrumentation includes X-ray, optical microscopes, a Coulter Counter for analyzing particle size, and equipment for determining the mechanical and physical properties of high temperature materials. High temperature instrumentation includes DTA (Differential thermal analysis), TGA (thermal gravimetric analysis), hot stage microscopes, thermal conductivity (to 2200° F) apparatus, and high temperature (2700° F) tensile strength apparatus. The High Temperature Materials Division also has a radiant heating facility. This facility consists of 474 quartz infrared lamps mounted in seven separate, water-cooled modules designed for independent control. Six horizontal zones of heat control are powered by 440 volt, 3-phase, 60-cycle circuits through three regulated power supplies and six ignitrons. The one-megawatt level of power operation has been tested and gave a heat flux of over 36 Btu/ft^2/sec 78/. With suitable positioning of the modules to accommodate the various configurations of component systems, a radiant thermal test with a precise thermal environment can be performed.

The Micromeritics Laboratory specializes in research involving finely-divided materials and is well equipped with many types of instruments. It has many of the standard devices for capturing and analyzing gases and particles. These include thermal and electrostatic precipitators, a Goetz Spectrometer, a Coulter counter, a Micromerograph, a Bahco classifier, optical and electron microscopes with photographic attachments, high volume air samplers, recording equipment, particle generators, an optical particle counter, a particle mass monitor, a SO_2-NO_2 gas analyzer, a total hydrocarbon gas analyzer, a mercury penetration pore volume instrument, and BET surface area instruments.

In addition to the laboratories described above there are many support groups within the Experiment Station. Those most likely to be used are discussed in Appendix I, page 32.

IV. DISCUSSION

The High Temperature Materials Division of the Engineering Experiment Station of the Georgia Institute of Technology is uniquely suited for research in fire technology. The years of experience of the personnel in areas of high temperature research and the available expertise and analytical capabilities at Georgia Tech indicate a natural combination for the type of research needed. This conclusion has been substantiated by visits by HTMD personnel to the Fire Technology Division of the National Bureau of Standards at Gaithersburg, Maryland, to SAF (Students Against Fires) on the Georgia Tech Campus, and to the conference at the University of Utah on fire prevention and control 79/. The literature study reported in the BACKGROUND further supported the belief that HTMD personnel can provide needed research efforts in fire technology.

Of particular interest to the High Temperature Materials Division is the relationship of carpeting to the fire problem. Since the manufacture of carpets is one of Georgia's largest industries, fire research related to carpets would be of great value to the state.

An opportunity that presents itself to Georgia Tech personnel is the intentional burning in the Atlanta area of dwellings and buildings destined for removal. These burnings are used for training firemen and conducting tests and are continually taking place and provide an excellent opportunity to obtain data. On July 25, 1973, a representative from the High Temperature Materials Division was invited to observe tests in motel rooms conducted by the Atlanta Fire Department and the Atlanta Building Authority. These tests have been summarized by Sales 80/. Currently, intentional dwelling burnings are being conducted by the DeKalb County Fire Department and are being observed by HTMD personnel.

Of related interest to actual fires is the construction of a permanent facility by the Georgia Fire Institute 81, 82/. Construction for this $1,380,000 installation will begin in the near future on a 20 to 30 acre site near the campus of the Southern Technical Institute at Marietta, Georgia. This facility will include administrative offices, classrooms, and full-size buildings for teaching and conducting demonstrations. This facility will also be available for conducting fire tests.

V. RECOMMENDATIONS

There are many areas of fire technology in which new research should be started and the present level of effort in other areas should be increased. Although there are many possible research programs, the following are specifically recommended:

A. The effect of holes in concrete floor slabs on the propagation of fires should be investigated.

B. The composition of the off-gases during both the initial heating and combustion stages of flammable materials should be determined.

C. The flammability of carpets and rugs exposed to thermal radiation should be investigated. In particular, background work needed for the development of a radiant heating standard test procedure should be conducted.

D. The effect of thermal radiation on the propagation of fires should be determined using full-sized objects.

E. A mobile fire technology laboratory should be designed.

F. Research should be undertaken on fires in actual dwellings and buildings making use of a laboratory such as the one mentioned in "E" above.

The research areas listed above are discussed in more detail in Appendix II, page 41.

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APPENDIX I

ADDITIONAL FACILITIES

WASTE UTILIZATION LABORATORY

The Waste Utilization Laboratory specializes in applied research to develop processes and equipment to utilize waste materials. Some of the waste materials that the laboratory has investigated are peanut hulls, sawdust, pine bark, hardwood chips, macadamia nut shells, cotton waste, nonmetallic automobile waste, and municipal waste. The basic experimental approach is pyrolysis of the waste material to produce a char, organic liquid, water, and noncondensible gases. The major resources to be obtained by this process are heat and/or char. The char in many cases can be converted to activated carbon, which is a high value product. The pyrolysis approach provides for the utilization of waste materials along with disposal in a nonpolluting manner.

The laboratory has analytical, bench scale, and pilot plant capabilities for experimental work in pyrolysis and related areas. The laboratory is equipped to analyze and characterize the products of pyrolysis. Specialized equipment includes a carbon, hydrogen, nitrogen, and oxygen analyzer, a differential scanning calorimeter and thermogravimetric analyzer, spectrophotometers, gas chromatographs, and a bomb calorimeter. Equipment available for conducting bench scale experiments include large tube furnaces, condenser trains, metering devices, muffle furnaces, grinding equipment, and recorders. The pilot plant waste converter facility was built for extended life at elevated temperatures and is capable of continuous, steady state operation at an input feed rate of approximately 1000 pounds per hour.

ANALYTICAL INSTRUMENTATION LABORATORY

An array of modern, sophisticated instruments for probing the fine structure of matter, equip this laboratory. These instruments, manned by expert scientists, may be applied in a coordinated manner to solve a problem, help develop a new product, or characterize a material. Modern specimen preparation and photographic facilities are available to complement the instruments so that a complete investigation can be carried out at one location. Included in the list of preparation equipment, are two diamond-knife ultramicrotomes. These are used to prepare thin sections from a wide variety of solids for electron optical viewing.

The basic tool for examining fine structure in materials is the optical microscope. A variety of these microscopes are available, including phase contract, metallographic and stereomicroscopes.

For studies requiring higher resolution than those available with light optics, there are five electron microscopes. Several of these instruments possess selected-area electron diffraction capability, while one instrument is equipped with a high-resolution electron diffraction stage.

The most versatile of these electron microscopes is the scanning electron microscope. Its great depth of focus, coupled with its high resolution capability, make possible the observation of surfaces whose degrees of roughness would exclude replica techniques.

Mapping the elemental distribution in a material surface to a spatial resolution of about one micron, can be accomplished in an electron-probe microanalyzer. Using a dispersive detector, it is capable of analyzing elements as light as boron.

For chemical identification and analysis of gross samples, conventional X-ray diffraction and fluorescence equipment are available. Ancillary equipment includes a high-temperature diffractometer stage and a vacuum fluorescence chamber.

To complete the list of analytical instruments is a 1-1/2 meter-grating spectrograph for the destructive analysis of metal elements in small specimens down to a few parts per million.

X-RAY DIFFRACTION LABORATORY

The X-ray Diffraction Laboratory is equipped to handle nearly all recognized powder and single crystal methods, using either film or counter techniques. Specimens may be studied at any temperature from 90° K to more than 1700° K, or as a continuous function of these temperatures. Specialized apparatus associated with the six basic x-ray units representing three different manufactures includes two single crystal diffractometers, two Lang-type topographic units, a precision camera, a Weissenberg camera, a low angle diffractometer and camera, a double crystal spectrometer, step-scanning diffractometers including one with a doubly bent crystal monochromator, a pole figure device, a vacuum x-ray fluorescence analysis units addition to the usual Laue and powder cameras. Electron diffraction and neutron diffraction are also included in the capabilities of the group which operates this laboratory.

MECHANICAL DESIGN SECTION AND MACHINE SHOP

Georgia Tech maintains a mechanical design section which has a staff of mechanical engineers and draftsmen with many years of experience in the design of engineering and scientific equipment. The group is prepared to undertake machine design, preparation of engineering drawings, and stress analysis. The group has designed complex radar antennas and drives, underwater devices for detonation studies, textile processing equipment, and specialized equipment of many other types.

The campus is provided with a number of highly specialized machine shops. The largest is a well equipped shop with over forty different types of machines and machine tools, specialized apparatus, and a staff of over twenty highly skilled personnel. Shop personnel are accustomed to working in close liaison liaison with research personnel and design engineers. This cooperation and the excellent facilities make possible the construction of most of the highly specialized equipment needed for sophisticated research projects.

The main machine shop occupies an eighty-five hundred square foot building with additional space for supplies; a 10-ton overhead crane with a 60 foot span operates the length of the building. Equipment includes fourteen engine lathes ranging in capacity from 6 to 24 inches, two Van Norman No. 12 universal milling machines, three horizontal and two vertical milling machines, a Gorton pantograph, a 3- by 12-foot planer, an 8- by 24-inch Thompson surface grinder, and an optical comparator. In addition, facilities are available for all types of welding, for sheet metal work and woodworking.

THE RICH ELECTRONIC COMPUTER CENTER

The Rich Electronic Computer Center provides analysis, research, programming, and digital computing services in the field of numerical analysis, the physical sciences, engineering, management, economics, information processing, and systems design. The Computer Center operates a large computer, the Univac 1108.

The Univac 1108 system has the following configuration: one 1108 processor; twelve input/output channels; 65,536 words of core storage (36 bit words) two magnetic memory drums (12 million characters each), two FASTRAN II mass storage units (132 million characters each); 4 magnetic tape units; and three 1004 sub-systems; each of the 1004 sub-systems consist of a small processor, a card reader, a card punch, and a line printer. Built-in double precision processing permits rapid computation with 18 decimal digit significance. Programming techniques include machine language, assembly language, FORTRAN V, ALGOL, and COBOL.

The center also has additional equipment that consists of (1) a CALCOMP digital plotter system, (2) an analog-to-digital conversion system, and (3) data preparation equipment (DPE). The DPE includes a sorter, collator, reproduction and summary punch, key punches, tabulatory machine and verifiers. Conversion equipment includes Flexowriters card to paper tape, and paper tape to card machines.

The Computer Center maintains an extensive program library which contains programs, procedures, and subroutines for executing elementary function evaluations, the solution of systems of linear equations, linear programming models, simulation, statistical curve fitting, matrix algebra, Eigenvalue calculations, complete multiple regression analysis, and many useful calculations applicable to specific problems.

PRICE GILBERT MEMORIAL LIBRARY

An essential strength for the undertaking of a research project in any field is a well-equipped and properly staffed library. The Georgia Tech Price Gilbert Memorial Library has developed outstanding collections of scientific and technical publications which are essential to the support of advanced study in scientific and engineering fields. Its holdings number over three hundred and fifty thousand bound volumes, sixty-three thousand technical reports, and three hundred thousand microtexts. Some ten thousand serial publications are currently received in addition to annual transactions and proceedings of the principal scientific and professional societies in America and abroad. The patent library has a complete file on all U. S. patents and accompanying drawings issued since May 7, 1946, a complete set of Official Gazette (which gives patent information back to 1872), and other reference literature on patents.

The library maintains a high degree of cooperation and communication with the Defense Documentation Center and makes frequent use of its services. It is an Atomic Energy Commission depository and has approximately forty-six thousand AEC documents on hand, including most of the non-classified reports issued by the AEC and its contractors. As a Federal Regional Scientific Report Center, Georgia Tech's library serves six southeastern states and Puerto Rico. In addition to the Atomic Energy Commission, the library serves as a depository for the Department of Defense, the Office of Technical Services, and the National Aeronautics and Space Administration. The Library also maintains files of reports from numerous private research institutions such as the Rand Corporation. A special group (Interlibrary Services) is responsible for the acquisition of materials not available on the Georgia Tech Campus.

PHOTOGRAPHIC AND REPRODUCTION LABORATORY

The Institute maintains a modern, well equipped photographic and reproduction laboratory for printing and illustrating reports. In addition to pressmen and photographers, a group of skilled draftsmen are available to assist project personnel. Facilities are maintained for collating and binding reports. Specialized Fastex General Radio, and other type cameras and stroboscopic lighting sources are available for high speed photography and other specialized photographic processes. The WF3, 16 mm, Fastax Camera can be used in research programs. The camera is capable of 8,000 frames per second, with an exposure time per frame of 1/24,000 second. The operating velocity at which an incident is photographed is determined from a 120-cycle neon light signal which provides timer marks on the sprocket side of the film. Higher frequency timer devices are available if required. The camera is capable of handling a 100-foot roll of film and utilizes a rotating prism. The film can be processed within two hours so that experimental set-ups can be evaluated with minimal delay.

APPENDIX II

PROPOSED RESEARCH AREAS

A. The Effect of Holes in Concrete Slabs Created by the Removal of Poke-Thru" Devices on the Fire Spread Characteristics of Concrete Slab Floors

A variety of "poke-thru" devices exist and studies have been made in regard to methods of installation and insulation. A well designed and well installed "poke-thru" device will produce no lowering of the fire resistance of a concrete slab floor. Perhaps, of greater concern than the "poke-thru" device itself is the hole in the floor which remains after removal of the "poke-thru". This quite often occurs, when, for example, a rearrangement of desks and/or offices is made.

A research effort should be undertaken which would investigate potential methods of fire spreading through "poke-thru" holes. As examples, the effect of an open hole, a hole covered with a metal plate, and a hole covered with a carpet on the fire endurance of a concrete slab should be studied.

B. Characterization of Toxic Gases and Smoke Emissions from Materials

As is well known, many victims of fires result from toxic gases rather than burns. The off-gases generated by fire, particularly in the early stage of preignition, have been shown to contain toxic gases. Toxic gases as well as smoke can be generated by both natural and synthetic materials.

A systematic study should be undertaken of toxic gas and smoke emissions from materials used in interior trim as well as furnishings. Such parameters as temperature and rate of heating as a function of time are expected to play a key role in such a study.

C. Thermal Radiation Effects in Fires in Which Rugs and/or Carpets play a Dominant Role

At present, the "pill" test is used as the standard test for carpets and rugs. There is interest in additional standards if feasible ones can be developed. A radiant heating test is being tentatively considered. Before such a standard can be developed, background work needs to be done. Studies in this area should be started.

D. The Role of Thermal Radiation in Fires

Thermal radiation is an important mechanism in the propagation of certain types of fires. Radiant heating experiments can be performed relatively easily on small specimens, but experiments on large objects cannot be accomplished readily. However, the radiant heating facility referred to previously would provide an ideal means of performing such experiments. For example, a full-sized sofa, chair, table, prefabricated wall or a combination of these could be exposed to a programmed intense thermal radiation.

Research on the ignition characteristics of furniture or wall section exposed to thermal radiation should be studied. This research would provide valuable data which will be necessary before dwelling fires can be understood.

E. A Mobile Fire Technology Laboratory

The intentional burning of old buildings and single family dwellings is used to provide training for firemen. This procedure offers a variety of opportunities for observing as well as obtaining experimental data on fires which approximate actual ones. One of the problems associated with this type of research is that the fires are set at various locations and in order to obtain a maximum amount of data, a mobile instrumentation laboratory would be a prerequisite. Another problem is that many of the senors could be destroyed during the fire so that the use of relatively inexpensive ones or the development of new ones will be required.

A study should be undertaken which would result in a detailed design for a mobile instrumentation laboratory for use in obtaining data on fires.

F. Fires in Houses and Buildings

After a laboratory as discussed under E, "A Mobile Fire Technology Laboratory," has been designed it should be constructed and used to obtain experimental data on fires in houses and buildings. These fires would include those set in old houses and buildings as well as real fires. For those fires that are set, sensors will be placed inside the house or building so that internal data would be obtained. Some data could be obtained externally, such as, for example, by using pyrometry and motion pictures.

APPENDIX III

BIOGRAPHICAL SKETCHES OF SELECTED RESEARCHERS

S. H. Bomar

W. H. Burrows

C. W. Gorton

E. Y. Keng

J. A. Knight

C. Orr

N. E. Poulos

A. T. Sales

J. D. Walton

Georgia Institute of Technology

BIOGRAPHICAL SKETCH

BOMAR, STEVE H., JR. -- Head of Fundamentals Branch
High Temperature Materials Division
Engineering Experiment Station

Education

B.Ch.E., Georgia Institute of Technology	1959
M.S.Ch.E., Georgia Institute of Technology	1961
Ph.D. in Ch.E., Georgia Institute of Technology	1967

Employment History

Continental Oil Company, Student Process Engineer	Summers of 1957, 1958
U. S. Army, First Lieutenant and Captain	1965-1967
Georgia Institute of Technology	
Student Instructor	1958
Student Assistant	1958-1959
Research Assistant	1959-1965
Research Engineer	1967-1968
Senior Research Engineer	1968-Present
Supervisor of Fundamentals Section	1967-1968
Head of Fundamentals Branch	1968-Present

Experience Summary: Taught freshman chemistry laboratories at Georgia Tech and worked on characterization and production of complex shapes of slip-cast fused silica. Worked on study of chemical reactions in aluminum-uranium oxide system with emphasis on production of nuclear reactor fuel elements capable of high temperature operation. Also studied hazards associated with use of uranium oxide dispersions in aluminum. Worked on impregnation of felted ceramic systems with water bearing materials for transpiration cooling. Studied use of thin metal films as thermometers and heaters in heat transfer investigations. During active duty in Army worked on devices for protection of personnel against laser radiation and production of lanthanide (rare earth) metal alloy thin films. After return to Georgia Tech from the Army, worked on development of high purity slip-cast fused silica structures using synthetic silicon dioxide as starting material. Was Co-Project Director with an Electrical Engineer on a program to develop a new method for measuring dielectric properties of radar window materials; this work extended the temperature range of these measurements from about 2500°F to 4000°F. Was Project Director on a program to investigate a new manufacturing process for microwave ferrite and garnet materials.

Patents

1. "Process for Preparing Ferrite and Garnet Raw Materials for Microwave Applications," U. S. Patent pending, co-inventor

Current Fields of Interest

Control of ferrite electromagnetic properties; novel manufacturing techniques for ceramic materials; measurement of surface temperatures by optical methods; use of ceramic materials for medical and dental applications; properties of electromagnetic window materials.

Major Reports and Publications

1. "Materials for High Temperature Nuclear Engineering Applications," Reports on U. S. Atomic Energy Commission Contract No. AT-(40-1)-2483, 1962-1964, coauthor
2. "Reactions in Al-34w/oU_3O_8 Dispersions," TID-21311, U. S. Atomic Energy Commission, July 1964, coauthor
3. "Ceramic Systems for Missile Structural Applications," Reports on Department of the Navy, Bureau of Naval Weapons Contract No. NOw-63-0143-d, 1964-1965, coauthor
4. "Heat Transfer from Electrically Heated Thin Metal Films to Water in Pool Boiling," Ph.D. Thesis, Georgia Institute of Technology, Atlanta, Georgia, June 1967
5. "A Multifunctional Protection System for Reentry Vehicles," Final Report for Department of the Army Contract DA-01-021-AMC-15260(Z), November 1967, coauthor
6. "High-Strength, Broadband, Lightweight Silicon Oxide Radome Techniques," Technical Reports on U. S. Air Force Contract No. F33615-67-C-1594, 1967, coauthor
7. "Dielectric Constant and Loss Tangent Measurement of High-Temperature Electromagnetic Window Materials," Technical Report AFWL-TR-69-92, AD 864731, December 1969, coauthor
8. "Dielectric Constant and Loss Tangent Measurement of High-Temperature Electromagnetic Window Materials," presented at USAF Annual Review of Reentry Systems Progress, Colorado Springs, Colorado, September 1969, coauthor
9. "Dielectric Constant and Loss Tangent Measurement of High Temperature Electromagnetic Window Materials," Proceedings of the Tenth Symposium on Electromagnetic Windows, Atlanta, Georgia, 29-31 July 1970, coauthor
10. "Manufacturing Techniques for Ferrites and Garnets Used in Phased-Array Radar 'U'," Technical Report QL-TR-71-1, U.S. Army Missile Command, AD 889348, February 1971, coauthor
11. "Investigation ot Spray Drying for the Production of Microwave Materials," presented at the 73rd Annual Meeting of The American Ceramic Society, Chicago, Illinois, April 1971, coauthor
12. "Properties and Behavior of Ceramics," presented at the Seminar "Ceramics for Biomedical Applications," Georgia Institute of Technology, Atlanta, Georgia, May 1971
13. "Production of Microwave Garnets by a Spray Drying Process," presented at the Annual Fall Meeting, Southeastern Section, American Ceramic Society, Chattanooga, Tennessee, November 1971, coauthor
14. "Manufacturing Techniques for Ferrites and Garnets Used in Phased-Array Radar 'U'," Technical Report QLC-TR-71-1, U.S. Army Missile Command, AD 902409L, November 1971, coauthor
15. "High-Temperature Complex Permittivity Measurements on Reentry Vehicle Antenna Window Materials," Technical Report AFWL-TR-71-189, AD 900411L, April 1972, coauthor

Major Report and Publications (Continued)

16. "High-Temperature Complex Permittivity Measurements on Antenna Window Materials," Proceedings of the Eleventh Symposium on Electromagnetic Windows, Atlanta, Georgia, 2-4 August 1972, coauthor
17. "High Temperature RF Transmission Tests on EM Windows Conducted at the French Solar Furnace," presented at the 1972 International IEEE/G-AP Symposium and Fall USNC/URSI Meeting, Williamsburg, Virginia, December 1972, coauthor
18. "Manufacturing Techniques for Ferrites and Garnets Used in Phased-Array Radar 'U'," Quarterly Reports on Contract DAAH01-72-C-0888, 1972-1973, coauthor
19. "Evaluation of Materials in a High Heat Flux Radiant Thermal Energy Environment," Final Report on Contract DAAG46-72-C-0189, January 1973, coauthor
20. "Complex Permittivity Measurements During High Temperature Recycling of Space Shuttle Antenna Window and Dielectric Heat Shield Materials," Final Report on Contract NAS1-11267, February 1973, coauthor

Georgia Institute of Technology

BIOGRAPHICAL SKETCH

BURROWS, WALTER H.--Principal Research Scientist, Technology Applications Group, Engineering Experiment Station

Education

A.B. in Chemistry, Emory University	1933
M.S. in Chemistry, Emory University	1938

Employment History

Spartanburg (S.C.) Junior College, Professor of Science	1938-1941
Georgia Institute of Technology, Assistant Professor	1941-1955
Associate Professor of Chemistry	1956-1965
Principal Research Scientist	1965-Present
Head of Industrial Products Branch	1956-1966
Head of Industrial Chemistry Laboratory, Technology Applications Group, Engineering Experiment Station	1966-Present

Experience Summary: At Georgia Tech, has taught chemistry and done research; also engaged in extensive consultation and advisory work for industry. Recent investigations have included corrosion and etching of metals, surface chemistry and its applications--e.g., adhesives, coatings, solvents, sealants, and lubricants, and studies in chemical equilibria and reaction kinetics.

Current Fields of Interest

Surface chemistry; chemical equilibrium and kinetics, corrosion and etching of metals; instruments for engineering computations; lubricants and lubrication.

Major Reports and Publications

1. "Hydration of the Ethylenic Linkage: I. Equilibrium between Isobutene, ter-Butyl Alcohol, and Water," J. Am. Chem. Soc. 63, 3000 (1941), co-author.
2. "The Nomographic Representation of Polynomials," J. Eng. Ed. 36, 361 (1946).
3. "Construction of Nomographs with Hyperbolic Coordinates," Ind. Eng. Chem. 38, 472 (1946).
4. "Nomograph for Formulas Containing Fractional Exponents," Ind. Eng. Chem. 38, 586 (1946).
5. "Graph Papers as Instruments of Calculation," Am. J. Phys. 17, 114 (1949).
6. "Graphical and Mechanical Methods of Computation," Research Engineer* (May 1950).

*Engineering Experiment Station Publication.

Major Reports and Publications (Continued)

7. "Methods of Calculating with Graph Papers," Product Engineer (April and June 1951).
8. "Construction of Circular Nomographs with Hyperbolic Coordinates," Ind. Eng. Chem. 43, 158 (1951).
9. "Construction of Nomographs with Hyperbolic Coordinates, General Hyperbolic Coordinates," Ind. Eng. Chem. 43, 1193 (1951).
10. "Construction of Three-dimensional Nomographs," Ind. Eng. Chem. 43, 1823 (1951).
11. "Some Properties of Hyperbolic Coordinate Systems," J. Franklin Inst., (August 1952).
12. "Computation Engineering at Industrial Levels," Research Engineer* (January, 1953).
13. "Methods for the Direct Construction of Nomographs from Data," Ind. Eng. Chem. 47, 33 (1955).
14. "Kinetic Studies of the Dissolution of Copper in Ferric Chloride Solutions," (A Masters' Thesis), 1957, with Robert E. Brooks.
15. "Science and the Art of Photoengraving," Research Engineer*(April 1958).
16. "Powderless Etching of Copper Photoengraving Plates," U. S. Patent 3,033,793, August 13, 1958, with L. W. Elston and J. W. Bradley.
17. "Nomograph for Antenna Measurements," Electronics (5 June 1959), with J. S. Hollis.
18. "Thread Compound, Antiseize and Sealing, for Aircraft Oxygen Systems," Final Report on Contract AF 33(616)-6090, 1959, with L. W. Elston.*
19. "Powderless Etching of Copper in Ferric Chloride Solutions," Final Technical Report, Project A-257 to Photoengravers' Research, Inc., April 1, 1960.*
20. "The Bugs in Surface Chemistry," Applications of Surface Chemistry in Industrial Problems," Research Engineer* (February 1961).
21. "Development of Test Methods and Formulations for Traffic Paints," a series of Annual Reports (1961-present), with W. R. Tooke, Jr.*
22. "That Tattle-tale Gray," The Building of Modern Detergents, Research Engineer,* (June, 1961).
23. "Kinetics of the Reactions Involved in the Ferric Chloride Etching of Copper Photoengraving Plates," Final Report on Contract AT(28-1)-202, Task II, 30 June 1961.*
24. "Physical Properties and Structural Characteristics of Polymers Resulting from Post-Effect Polymerization," Final Report on Contract No. AT(38-1)-202, Task X, Atomic Emergy Commission, with L. W. Elston, 1963.*
25. "Effects of High Energy Ionizing Radiation on Colloidal Systems and Suspensions," Final Report on Contract No. AT(38-1)-202, Task IX, Atomic Energy Commission, with W. J. Corbett, P. E. Gaffney, and Clyde Orr, Jr., 1963.*
26. "Kinetics of the Copper-Ferric Chloride Reaction and the Effects of Certain Inhibitors," I. & E. C. Process Design and Development Quarterly, V. 3, No. 2, p. 149, with C. T. Lewis, Jr., D. E. Saire, and R. E. Brooks, April, 1964.

*Engineering Experiment Station Publication.

27. "A Method of Approximating the Carbonation of a Beverage When Air is Present in the Bottle," Proc. Soc. Soft Drink Technologists, April, 1964.
28. "Exhaust Gases from Engines Having Special Controls," Final Report, N.I.H. Research Grant No. AP-00225, with C. M. Mobley, Jr., August, 1965.*
29. "Use of Radioisotopes in Development of Test Methods and Formulations for Traffic Paints," Final Technical Report on Research Project HPS-1(60), State Highway Department of Georgia, with W. R. Tooke, Jr., September, 1965.
30. "Graphical Representation of Statistical Functions," Final Report, Research Grant No. GM 13007, PHS, Institute of General Medical Science, 1968.
31. "Molecular Science in Surface Coatings," J. Paint Technology, 41, No. 529, February 1969.
32. "Tracer Sensitive Tapes," Final Technical Report on Research Project No. NAS8-26759, George C. Marshall Space Flight Center, NASA, November 31, 1971, with L. W. Elston.
33. "Cost Analysis of the Extraction of Protein from Peanut Meal and Presscake," Final Technical Report, Project A-1395, to Georgia Agricultural Commodity Commission for Peanuts, December, 1972.

Books

1. Graphical Methods in Engineering Computations, New York, Chemical Publishing Company, 1965; also, London, The MacMillian Company, 1965.

Educational Television--Lecture Demonstrations

"Surface Tension"--WETV, WGTV
"How Man's Knowledge of Chemistry Has Improved His Living," with W. R. Tooke, Jr.--WETV, WGTV
"Molecular Motion"--WETV

Memberships and Offices

American Chemical Society
Secretary, Georgia Section, 1954-1957
Chairman, Georgia Section, 1960
Georgia Academy of Science (Fellow)
Secretary, Chemistry Section, 1955
Chairman, Chemistry Section, 1956
New York Academy of Sciences
American Institute of Chemists (Fellow)
American Institute of Chemical Engineers
American Association for Advancement of Science
National Fire Protection Association
Phi Beta Kappa
Sigma Xi

Listings

American Men of Science
Leaders in American Science
Dictionary of International Biography
Who's Who in the South and Southwest
Who's Who in Education in the South
Who Knows, and What
Transportation and Products Legal Directory

Georgia Institute of Technology

BIOGRAPHICAL SKETCH

GORTON, CHARLES W.--Professor, School of Chemical Engineering and Division Adviser

Education

B.S.M.E., Louisiana Polytechnic Institute	1950
M.S.M.E., Georgia Institute of Technology	1951
Ph.D.M.E., Purdue University	1953

Employment History

Georgia Institute of Technology, Graduate Assistant	1950-1951
Purdue University, Westinghouse Research Fellow	1951-1952
Purdue University, National Science Fellow	1952-1953
United Aircraft Research Dept., East Hartford, Conn.	
Research Engineer	1953-1955
Georgia Institute of Technology	
Associate Professor of Mechanical Engineering	1955-1960
Professor of Mechanical Engineering	1960-1965
Professor of Chemical Engineering	1965-Present
Consultant to the Martin Company, Orlando, Florida	1962-1964
Aerospace Sciences Research Lab, The Martin Co., Orlando, Fla.	
Senior Research Scientist	Summer 1963
Consultant to Oak Ridge National Laboratory	1967-1968

Experience Summary: At United worked in the Thermodynamics Group in the Analysis Section and performed analytical work in combustion, heat transfer, fluid flow, aerodynamic heating, and de-icing. At United also taught undergraduate courses in Thermodynamics and Fluid Mechanics for the Pratt and Whitney Training School. In the Mechanical Engineering Department at Georgia Tech taught undergraduate courses in Heat Transfer, Fluid Mechanics, Thermodynamics, and Combustion, and graduate courses in Thermodynamics, Fluid Mechanics, Mass Transfer and Combustion. While in the Mechanical Engineering Department helped to develop the Ph.D. program and advised many M.S. and Ph.D. theses in Heat Transfer and Fluid Flow, some of which were supported by research grants pertaining to fluid flow and free convection heat transfer. Presently advising Ph.D. theses in the following areas: combustion, pack cementation, and fluid flow. In the Chemical Engineering Department has taught undergraduate courses in Transport Phenomena and graduate courses in Fluid Flow and Heat Transfer. At the Engineering Experiment Station has worked on hydroocyclones, reentry heating, aerodynamic heating for low-altitude supersonic flight, arc-plasma testing, rain erosion, and chemical vapor deposition. At Martin worked on combustion, high velocity flow instrumentation, and heat transfer in dissociated environments.

Current Field of Interest

Transport phenomena including: aerodynamic heating and ablation; combustion including: heterogeneous combustion and combustion in jet mixing regions (at sub and supersonic speeds); rain erosion; chemical vapor deposition; and waste management.

Major Reports and Publications

1. "Preliminary Investigation of the Mestastable Limit of Liquid Water," M.S. Thesis, Georgia Institute of Technology, 1951
2. "Head Transfer Coefficients Between Drops of Liquid and a Hot Plate," Ph.D. Thesis, Purdue University, 1953
3. "Two Confidential Research Memoranda," United Aircraft Research Dept., 1953-1954
4. "An Evaluation of the Hot Air Engine for Helicopter Use," Research Memorandum, United Aircraft Research Dept., 1954
5. "Research Report M-0869-1 concerning anti-icing heating requirements of propeller spinners. United Aircraft Research Dept., 1955
6. "Analytical Solution of a Thermal Entrance Problem," Appendix A, Final Report, Office of Ordnance Research Project No. 1164 on "Wetting Effect on Heat Transfer," 1957
7. "The Mechanical Engineering Approach to Systems Engineering," The Research Engineer, Georgia Institute of Technology (April 1962)
8. "Non-Isothermal Velocity Profiles," A communication to the Editor, A. I. Che. Journal, (January 1963), with others
9. "Transient Response of a Transpiration-Cooled Slab Exposed to a Constant Heat Flux," Presented in Aerospace Forum I at 31st Annual IAS Meeting, January 1963, bound in Fairchild Fund Paper No. FF-34, with others
10. "Research Areas in High Velocity Flow Instrumentation," Martin-Orlando Report OR 3717, January 1964
11. "Viscous Fluid Flow Under the Influence of a Resonant Acoustic Field," A.S.M.E. Journal of Heat Transfer (February 1964), 97-106, with others
12. "The Combustion of Pyrolytic Boron Nitride," Progress in Astronautics and Aeronautics (Vol. XV) AIAA (1964), with others
13. "An Analysis of a Compressible, Turbulent Boundary Layer on a Chemically Reacting Pyrolytic Boron Nitride Surface," AIAA Entry Technology Conference, Williamsburg, Virginia, 12-14 October 1964, with others
14. "Through-Flow Drying of Tufted Textile Materials," Textile Research Journal, 1031-1039 (December 1964), with others
15. "An Analysis of a Compressible Turbulent Boundary Layer on a Chemically-Reacting Pyrolytic Boron-Nitride Surface," Technical Note, AIAA Journal Vol. 3, No. 7, July 1965, pp 1354-1356, (previously presented see item 13 above), with others
16. "Simultaneous Heat, Momentumn and Mass Transfer in the Trough-Flow Drying of Agricultural Products," presented at the Southeast Regional Meeting of the American Society of Agricultural Engineers, Chattanooga, Tenn., February 7, 1966, with others
17. "Design and Development of an Electromagnetic Window for Air Lift Reentry Vehicles," Final Technical Report AFAL-TR-66-34, March 1966, performed under USAF Contract 33(657)-11504, with others
18. "Design/Development of Slip-Cast Fused Silica Nose Cap for Trailblazer III Vehicle," presented at the U. S. Air Force-Georgia Tech Symposium on Electromagnetic Windows, Atlanta, Georgia, June 1-3, 1966, with others
19. "A Hydrosonic Rain Erosion Test Program," presented at the U. S. Air Force-Georgia Tech Symposium on Electromagnetic Windows, Atlanta, Georgia, June 1-3, 1966, with others

Major Reports and Publications (continued)

20. "A Feasibility Study for an Integrated Radome Antenna (RADANT)," U.S. Air Force-Georgia Tech Symposium on Electromagnetic Windows, Atlanta, Georgia, June 1-3, 1966, with others
21. "Ceramic Systems for Missile Structural Applications," Final Summary Report, October 1966, performed under Navy Contract NOw-63-0143-d, Bureau of Naval Weapons, with others
22. "Development of Lightweight Broadband Radomes From Slip-Cast Fused Silica," Final Technical Report AFAL-TR-67-56, April 1967, performed under USAF Contract 33(615)-3445, with others
23. "Filament Wound Silica Radome Techniques," Final Technical Report AFAL-TR-67-65, April 1967, performed under USAF Contract 33 (615)-3330, with others
24. "Ceramic Systems for Missile Structural Applications," Quarterly Reports on Naval Ordnance Systems Command, Contract N00017-67-C-0053, 1967, with others
25. "Rain Erosion of Ceramic at High Mach Numbers," Proceedings of the Second Conference on Rain Erosion, Meersburg, West Germany, August 1967, with others
26. "Rain Erosion at High Mach Numbers," International Conference on Electromagnetic Windows, Paris, France, September 1967, with others
27. "Development in Ablation and Combustion Applicable to Chemical Vapor Deposition," Proceedings of the Conference on Chemical Vapor Deposition of Refractory Metals, Alloys, and Compounds, Gatlinburg, Tennessee, September 1967
28. "Chemical Vapor Deposition Statistical Parametric Study," Proceedings of the Conference on Chemical Vapor Deposition of Refractory Metals, Alloys, and Compounds, Gatlinburg, Tennessee, September 1967, with others
29. "Thermal Tests of Slip-Cast Fused Silica Radomes with Uncooled Attachments," USAF Avionics Laboratory-Georgia Tech Symposium on Electromagnetic Windows, Atlanta, Georgia, June 12-14, 1968, with others
30. "Uncooled Attachment Design for Slip-Cast Fused Silica Radomes," Technical Report No. 4 on Contract N00017-67-C-0053, April 1970
31. "Evaluation of Ceramic Coatings for Rain Erosion Protection," Proceedings of the USAF-Georgia Tech Symposium on Electromagnetic Windows, Atlanta, Georgia, July 1970, with others

Georgia Institute of Technology

BIOGRAPHICAL SKETCH

KENG, EDWARD Y. H.--Senior Research Engineer, Engineering Experiment Station

Education

B.S. in Ch.E., Tunghai University	1959
M.S. in Ch.E., Georgia Institute of Technology	1964

Employment History

Rice University, Research Assistant	1961-1962
Georgia Institute of Technology	
Engineering Experiment Station	
Graduate Research Assistant	1962-1966
Research Engineer	1966-1970
Senior Research Engineer	1970-Present

Experience Summary

Began career by working on investigations into the solubilities of gases in liquids, photophoretic behavior of particulates in atmosphere, and particle size classification. Since 1964 has conducted and directed investigations into the dispersion and generation of aerosols, radiant heat transfer to particle-seeded gases, liquid atomization, thermal force on particulates, electrostatic effects on dispersed particles, coagulation of airborne particles, formation of particulates from gaseous impurities in air under the influence of radiation, condensation and nucleation phenomena of hygroscopic particulates, aerosol sampling and particulate size determination. Also engaged in the development of centrifugal classifiers, aerosol generators, and gas pycnometer. Member, American Institute of Chemical Engineers, American Chemical Society, Fine Particle Society, and Society of Sigma Xi.

Current Fields of Interest

Particulate technology; air pollution; radiant heat transfer.

Patents

1. "Method and Apparatus for Volume Measurement" U. S. Patent No. 3,453,881 (1969); British Patent No. 1,220,313 (1971).
2. "Method for Volume Measurement" U. S. Patent No. 3,585,861 (1971)

Major Reports and Publications

1. "An Experimental Study of the Solubilities of Nitrous Oxide in Normal Heptane and Normal Dodecane," Report prepared for Scott Corporation, Rice University, 1962, with R. Kobayashi.

2. "Photophoresis as Related to Meteorological Phenomena," Final Report on Project B-222, Contract No. G-19273, National Science Foundation, 1963, with C. Orr, Jr.
3. "Light Boundary Effect in Photophoresis," Nature 200, 352, 1963, with C. Orr, Jr.
4. "Particle Trajectories in a Centrifugal Classifier," Final Report on Projects B-248 and B-265, Research Grant OH-00130-01 and 02, Dept. of Health, Education, and Welfare, 1964, with others.
5. "An Investigation on Photophoresis," M. S. Thesis in Chemical Engineering,1964.
6. "Heat Transfer to a Gas Containing a Cloud of Particles," Special Report on Project A-635-002, Research Grant NsG-273-62, National Aeronautics and Space Administration, 1962-1965, with others.
7. "Photophoresis in Stratosphere, "Journal of the Atmospheric Science, 21, No. 5 475-78, 1964, with C. Orr, Jr.
8. "Heat Transfer to a Gas Containing a Cloud of Particles," NASA CR-54441, Nuclear Reactor Division, NASA Lewis Research Center, Cleveland, Ohio, July 1965, with others.
9. "Heat Transfer to a Gas Containing a Cloud of Particles," NASA CR-325, National Aeronautics and Space Administration, Washington, D. C., November 1965, with others.
10. "Thermal Precipitation and Particle Conductivity," Journal of Colloid and Interface Science, 22, 107-16, 1966, with C. Orr, Jr.
11. "A Study of Vibrating-Capillary Atomizers," Final Report on Project B-279, Research Grant AP-00351, Dept. of Health, Education, and Welfare, 1967, with others.
12. "Aerosol Research in Chemical Engineering at Georgia Tech," Air Pollution Control Association Journal, 17, 590-2, September 1967, with others
13. "Investigation of Radiant Heat Transfer to Particle-Seeded Gases for Application to Nuclear Rocket Engine Design," NASA CR-953, National Aeronautics and Space Administration, Washington, D. C., 1967, with C. Orr, Jr.
14. "Particle Dynamics in Centrifugal Fields," Power Technology, 1, No. 5, 305-15, 1968, with others.
15. "Particle Size and the Rate of Radiant Heat Transfer to Gas-Suspended Particles," Powder Technology, 1, No. 6, 323-7, 1968, with C. Orr, Jr.
16. "The Influence of Electrostatic Effects on the Dispersion of Organic Powders," Final Report on Project A-957, Contract DA 18-035-AMC-1058 (A), U. S. Army Edgewood Arsenal Chemical Research and Development Laboratories, August 1968, with others.
17. "Characteristics of Atmospheric Hygroscopic Particulates under Changing Humidity Conditions," presented at 156th ACS National Meeting, Atlantic City, New Jersey, September 1968.
18. "Heat Transfer to a Gas Containing a Cloud of Particles," Final Report on Project A-635, Research Grant NsG-273-62, National Aeronautics and Space Administration, January 1969, with C. Orr, Jr.
19. "Hysteresis in Smog and Fog Disappearance," Final Report on Project B-330, Contract No. AP-00345, Dept. of Health, Education, and Welfare, February 1969, with others.
20. "Growth of Hygroscopic Particles in Polluted Air," presented at 1969 AIChE Ga.-Fla. Joint Meeting, Daytona Beach, Florida, May 1969.
21. "Air and Helium Pycnometer," Powder Technology, 3, No. 3, 179-180, 1969.
22. "Application of Zoning Techniques in Practical Radiative Energy Transport Problems," Proceeding of a Symposium on Research on Uranium Plasmas and Their Technological Applications, NASA SP-236, 273-281, 1970.
23. "Gaseous Impurities and Nuclear Condensation on Airborne Sodium Chloride Particles," Environmental Science and Technology, 4, No. 5, 417-420, (1970).

24. "Coagulation Behavior of Typical Industrial Aerosols," presented at 1970 AIChE Ga.-Fla. Joint Meeting, Daytona Beach, Florida, May 1970.
25. "Radiant Heat Transfer to Absorbing Fluid Media," Journal of Chemical Engineering of Japan, 3, No. 2, 171-176 (1970) with C. Orr, Jr.
26. "Homogeneous Nucleation of Aqueous NaCl Solutions," presented at 45th National Colloid Symposium, Atlanta, Georgia, 1971.
27. "Identification of Pollution Hazards Associated with the Products of Wood Burning," Final Report on Project B-387, Georgia Forest Research Council, 1971, with J. H. Burson, III.
28. "Aerosols Produced by X-Rays," Journal of Colloid and Interface Science, 39, 94-102 (1972).
29. "Homogeneous Nucleation in Contaminated Atmospheres," Final Report on Project B-364, Contract No. AP 00816, Environmental Protection Agency, 1972.
30. "Aerosol Size Determination in the Submicron Region by Thermophoresis," Aerosol Science, 3, 45-53 (1972).
31. "Formation of Nonvolatile Particulates from Organic Vapors," Final Report on Project B-358, Contract No. OH 00329, Public Health Service, 1972.
32. "Aerosol Produced by X-Rays," in Part I, AEROSOLS AND ATMOSPHERIC CHEMISTRY (G. M. Hidy, editor) Academic Press, New York, 1972.
33. "Jet Exhaust Reactions," Final Report, Project A-1437, Contract No. F 19628-72-C-0353, Air Force Cambridge Research Laboratories, 1973.

Georgia Institute of Technology

BIOGRAPHICAL SKETCH

KNIGHT, JAMES A., JR.--Research Professor, Engineering Experiment Station

Education

B.S. in Chemistry, Wofford College	1942
M.S. in Organic Chemistry, Georgia Institute of Technology	1944
Ph.D. in Organic Chemistry, Pennsylvania State University	1950

Employment History

U.S. Army, Oak Ridge, Manhattan District	1944-1945
Georgia Institute of Technology	
Assistant Professor, School of Chemistry	1950-1954
Associate Professor, School of Chemistry	1954-1958
Research Associate Professor, Engineering Experiment Station	1958-1962
Research Professor, Engineering Experiment Station	1962-Present

Experience Summary: Engaged in teaching and research at Georgia Tech from 1950-1957, and since 1958 has devoted most of time to research. Research work has been in the areas of synthetic organic chemistry, radiation chemistry of organic systems, and waste utilization with emphasis on lignocellulosic and cellulosic waste. Prior to 1957, had considerable research experience in synthetic organic research. Radiation chemistry investigations have been on the radiation chemistry of highly branched hydrocarbons, cyanogen-hydrocarbon systems, and non-hydrocarbon monosubstituted benzenes. For the past several years, involved in pyrolytic studies of lignocellulosic and cellulosic wastes, such as peanut hulls, pine bark, wood waste, and cardboard. These studies include determinations of the yields of various phases of material from pyrolysis at different conditions, and characterization and evaluation of the char, organic liquid phase, non-condensible gases, and water phase from the pyrolysis of the different waste materials. The research with waste materials is directed toward the development of processes for the utilization of the waste materials and marketable products. Had extensive experience in the utilization of gas chromotography for the analysis of gases and organic materials.

Current Fields of Interest

Utilization of lignocellulosic and cellulosic waste materials; radiation chemistry of organic systems (including both radiation-effects studies and radiation-synthesis studies); organic chemistry; gas chromatography

Major Reports and Publications

Publications

1. "The Synthesis of Quinolines by the Pfitzinger Reaction," Journal of American Chemical Society 66, 1893 (1944), with P. K. Calaway.

Major Reports and Publications

Publications (Continued)

2. "Reduction of Aliphatic Nitriles," Journal of American Chemical Society 74, 4500 (1952), with Harry D. Zook.
3. "Addition of Hydrogen Bromide to trans-4-Heptenoic Acid," Journal of American Chemical Society 76, 2302 (1954), with Harry D. Zook.
4. "Synthesis of Some Octenoic Acids," Journal of Organic Chemistry 24, 400 (1959), with James H. Diamond.
5. "Gas Chromatographic Analysis in Fractional Distillation of Multi-Component Systems," Journal of Chromatography 5, 179 (1961), with Fred Sicilio and Neal House.
6. "Technique for Determination of Molecular Weight with a Small Volume," Review of Scientific Instruments 32, 355 (1961), with Fred Sicilio and Bert Wilkins.
7. "Semi-Micro Cryoscopis Molecular Weight Determination with a Thermistor Thermometer," Analytica Chimica Acta 25, 317 (1961), with Fred Sicilio, Bert Wilkins, and D. K. Davis.
8. "An Inexpensive, Versatile, Multi-Column Gas Chromatograph for Students," Journal of Chemical Education 38, 506 (1961), with Fred Sicilio, H. Bull, and R. C. Palmer.
9. "H_2 and C_1-C_7 Yields from the Radiolysis of 2,2,4-Trimethylpentane," Journal of Physical Chemistry 65, 2109 (1961), with Fred Sicilio, R. L. McDaniel, and R. C. Palmer.
10. "A Novel Method for Preparing Small Particulate Radioactive Sources of High Intensity from Attapulgite Clay," International Journal of Applied Radiation and Isotopes 12, 141 (1961), with Fred Sicilio and R. J. Klett.
11. "Radiation-Induced Cyanogenation of Organic Liquids," International Journal of Applied Radiation and Isotopes 14, 239 (1963), with C. J. Bryan and R. A. Stokes.
12. "Radiolysis Products of C_8 and Greater Carbon Content from 2,2,4-Trimethylpentane," Journal of Physical Chemistry 67, 921 (1963), with R. L. McDaniel and Fred Sicilio.
13. "Radiolysis Products from the X-Irradiation of 2,2,4,6,6-Pentamethylheptane," Radiation Research 19, 359 (1963), with Fred Sicilio.
14. "Radiolysis of 2,2,4-Trimethylpentane and 2,2,4,4-Tetramethylpentane," Radiation Research 23, 319 (1964), with C. T. Lewis.
15. "Radiolysis of Cyanogen-Cyclohexane Mixtures," Journal of Physical Chemistry 69, 678 (1965), with R. Stokes and D. Bowen.
16. "A Sampling Device for Viscous and Solid Materials for Gas Chromatography," Journal of Chromatography 18, 158 (1965), with C. T. Lewis.
17. "Direct Pressing of Fibers for Infrared Spectroscopic Studies," Textile Research Journal 37, No. 11, 924-927 (1967), with M. P. Smoak, R. A. Porter, and W. E. Kirkland.
18. "A Crystallinity Study of Cellulosic Fibers Employing Deuteration and Infrared Spectroscopy," Textile Research 39, No. 4, 324-328 (1969), with H. Lamar Hicks and Kenneth W. Stephens.
19. "Gas Chromatographic Analysis of γ-Irradiated Nitrobenzene for Biphenyl and Nitroaromatic Products," Journal of Chromatography 48, 526-529 (1970).

Major Reports and Publications

Publications (Continued)

20. "Arylation of Nitrobenzene Induced by γ-Radiation," Radiation Research 44, 50-58 (1970).
21. "Gas Chromatographic Analysis of γ-Irradiated Aniline for Aminoaromatic Products," Journal of Chromatography 56, 201-208 (1971).
22. "Aerosols Produced by X-Rays," Journal of Colloid and Interface Science 39, 94-102 (1972), with Edward Y. H. Keng, Richard R. C. Chu, and Clyde Orr, Jr.
23. "Radiolysis of Aniline," Radiation Research 51, 590-598 (1972).
24. "Radiolysis of Nitrobenzene," Radiation Research 52, 17-24 (1972).
25. "Phenylation of Nitrobenzene by γ-Radiation," Radiation Research 54, 207-211 (1973).
26. "Gas Chromatographic Conditions for the Analysis of γ-Irradiated Benzonitrile for Cyanoaromatic Products," Journal of Chromatography, 79, 325-328 (1973).

Reports

1. "Radiation Chemistry of Organic Substances," Final Report on Subcontract 1082 to W-7402 ENG-26, January 1959
2. "Radiation-Induced Cyanogenation of Organic Compounds," Final Report on Contract No. AT-(38-1)-202, SRO-78, February 1963
3. "Radiation Chemistry of Organic Systems," Final Report on Contract No. AT-(40-1)-2490, August 1964
4. "Evaluation of Pyrolysis as a Means of Resource Recovery from Solid Wastes of the Cotton Industry," Final Report, Project A-1402, Cotton, Inc., October, 1972

Georgia Institute of Technology

BIOGRAPHICAL SKETCH

ORR, CLYDE, JR. -- **Regents' Professor of Chemical Engineering and Associate Director, School of Chemical Engineering.**

Education

B. S. in Ch.E., University of Tennessee	1944
M. S. in Ch.E., University of Tennessee	1948
Ph.D. in Ch.E., Georgia Institute of Technology	1953

Employment History

U. S. Navy, CIC Officer	1944-1946
TVA, Wilson Dam, Alabama, Chemical Engineer	1946-1947
Georgia Institute of Technology	
Research Engineer	1948-1952
Research Assistant Professor	1952-1953
Research Associate Professor	1953-1958
Research Professor of Chemical Engineering	1958-1962
Professor of Chemical Engineering	1962-1966
Regents' Professor of Chemical Engineering	1966-Present

Experience Summary: Began career with process development for phosphoric acid production, but in research at Georgia Tech shifted largely into micromeritics (fine particle technology). Since 1949 has conducted and directed investigations into the chemical engineering and physical chemistry of a wide variety of types of finely divided materials, including colloidal systems, aerosols, and powders in mass. Work has led from scientific studies with bacteria into natural cloud phenomena and into the basic properties exhibited by matter--such as surface energy, nucleation ability, radiation responses, inhalation effects, and the behavior of particles in space. Engineering interests center around unit operations that involve particulate matter, e.g., atomization, grinding, fluidization, filtration, pneumatic conveying, and the like. Graduate courses in micromeritics taught in the School of Chemical Engineering; undergraduate course teaching includes heat transfer, comprehensive problems, and process control. Listed in *World Who's Who in Science*, *Who's Who in the South and Southwest*, *The Authors and Writer's Who's Who*, *Who's Who in Engineering*, *American Men of Science*, *Dictionary of International Biography*, and *The Directory of British and American Writers*. Director, American Association for Contamination Control (1961-63). Consultant at various times to Oak Ridge National Laboratory, Xerox Corp., Allen-Bradley Co., Rohm and Haas Co., Technical Operations Research, National Air Pollution Control Administration of USPHS, and others. Member, A.I.Ch.E., ACS.

Current Fields of Interest

Micromeritics (fine particle technology); atmospheric phenomena; instrumentation.

ORR, CLYDE, JR. Biographical Sketch

Major Reports and Publications

1. "A Study of the Sulphur Dioxide, Sulphur Trioxide, Chlorides, Acid, and Dust in the Air in the Vicinity of Bush Field near Augusta, Ga.," Prepared for the Chamber of Commerce, August, Ga., March 1949, with J. M. DallaValle.
2. "Research on Surface Properties of Fine Particles," 8 reports on Contract W 36-039 SC-38258, 1949-1951, with J. M. DallaValle and others.
3. "Investigation of Aggregation of Fine Particle Matter Suspended in Air," 4 reports on Contract DA 18-064-CML-402, 1950-1951, with J. M. DallaValle with others.
4. "Fine Particles," Scientific American 183, 50-53 (1950).
5. "Limitations of the Arealometer Method for the Measurement of Fiber Diameters," Textile Research Journal 20, 676-82 (1950) with J. M. DallaValle and others.
6. "Fitting Bimodal Particle Size Distribution Curves," Ind. Eng. Chem. 43, 1377-80 (1951), with J. M. DallaValle and others.
7. "Research on Surface Properties of Fine Particles," 8 reports on Contract DA 36-039 SC-5411, 1951-1953, with J. M. DallaValle and others.
8. "Investigation of Aggregation of Fine Particle Matter Suspended in Air," 8 reports on Contract DA 18-064 CML-490, 1951-1953, with J. M. DallaValle and others.
9. "A Rapid Liquid-Phase Adsorption Method for the Determination of the Surface Area of Clays," J. Am. Cer. Society 56, 58-60 (1952), with others.
10. "A Thermal Precipitator for Aerobacteriology," Science 116, 368 (1952), with T. W. Kethley and M. T. Gordon.
11. "Surface Areas of Metals and Metal Compounds: A Rapid Method of Determination," J. of Metals 4, 657-60 (1952), with others.
12. "Settling of Particles in a Thermal Gradient," Proceedings of the Third Midwestern Conference on Fluid Mechanics, 741-57, 1953, with J. M. DallaValle and H. G. Blocker.
13. "Dynamic Gas Adsorption Methods of Surface Area Determination," J. Phys. Chem. 57, 517-20 (1953), with others.
14. "The Aggregation of Aerosols," Report of Symposium V--Aerosols, Army Chemical Center, Md., June 1953, with J. M. DallaValle.
15. "Standardization of Surface Properties of Fine Particles," 4 reports on Contract DA 36-039 SC-42588, 1953-1954, with J. M. DallaValle and H. G. Blocker.
16. "An Investigation of Factors Determining Aggregation of Fine Particle Matter," 4 reports Contract DA 18-064 CML-2379, 1953-1954, with others.
17. "Heat-Transfer Properties of Liquid-Solid Suspensions," Heat-Transfer-Research Studies for 1954, Chemical Engineering Progress Symposium Series, No. 9, Vol. 50, 29-45, 1954, with J. M. DallaValle.
18. "Thermal Precipitation in Air Pollution Studies," J. of Air Pollution Control Association 4, 1, 1-4 (1954), with M. T. Gordon.
19. "A New Method for the Measurement of Aerosol Electrification," J. Colloid Sci. 9, 70-80 (1954), with B. L. Hinkle and others.
20. "The Aggregation of Aerosols," Brit. J. Appl. Physics, Supplement No. 3, 198-206 (1954), with J. M. DallaValle and others.

Major Reports and Publications (continued)

21. "Investigations of the Relation, If Any, Between Viability and Electric Charges on Airborne Micro-organisms or Particles Containing Such Micro-organisms," 4 Reports on Contract DA 18-064 CML-2570, 1954, with others.
22. "An Investigation into the Growth of Small Aerosol Particles with Humidity Change," 8 Reports on Contract AF 19(604)-1086, 1954-1956, with others.
23. "Thermal Conductivity of Granulated Beds," Ind. Eng. Chem. 47, 356 (1955).
24. "The Viscosity of Suspension of Spheres," J. of Colloid Science 10, 24-8 (1955) with H.G. Blocker.
25. "Studies and Investigations of Agglomeration and Deagglomeration," 20 Reports on Contract DA 18-064-404 DML-88, 1955-1957, with J.M. DallaValle.
26. "The Density and Size of Airborne Serratia marcescens Cells," J. Bacteriology 71, 315-17 (1956) with M.T. Gordon.
27. "Thermal Precipitation for Sampling Airborne Micro-organisms," J. Appl. Microbiology 4, 116-18 (1956), with M.T. Gordon and Margaret C. Kordecki.
28. "A Continuous Thermal Precipitator for Aerosol Sampling," Final Report on Grant from University Center in Georgia, 1956.
29. "Aerosol Studies at Georgia Tech," Research Engineer 12, 2, 15-19 (April 1957).
30. "Airborne Micro-organisms as Analytical Tools in Aerosol Studies," J. of the Air Pollution Control Assoc. 7, 16-20 (1957), with T.W. Kethley, E.L Fincher and J.M. DallaValle.
31. "The Behavior of Condensation Nuclei Under Changing Humidities," J. of Meteorology 15, 240-2 (1958), with F.K. Hurd, W.P. Hendrix, and C. Junge.
32. FINE PARTICLE MEASUREMENT, The Macmillan Company, New York, N.Y., 1959 with J. M. DallaValle.
33. "Aerosol Size and Relative Humidity," J. Colloid Sci. 13, 472-82 (1958) with F.K. Hurd and W.J. Corbett.
34. "A Thermal Precipitator for Continuous Aerosol Sampling," The Review of Scientific Instruments 28, 129-30 (1958), with R.A. Martin.
35. "A Study of Equilibria Involved Between Darex Off-Gases and Solutions," 8 Reports on Subcontract 1373 under W-7405-ENG-26, 1958-1959, with others.
36. "A Study of the Solubility and Rate of Solution of Fine Aerosol Particles," 8 Reports on Contract AF 19(604)-1970, 1958-1959, with others.
37. "An Investigation of Thermal Force with Particular Reference to Materials of High Thermal Conductivity," Annual Report on NSF Grant G7051, 1960, with others.
38. "An Investigation of Two-Phase Thermal Conductivity," 8 Reports on Contract DA 91-009 ORD-704, 1958-1960, with others.
39. "Surface Energy of Smog and Fog Nuclei," Annual Report on NIH Grant S-79, 1958-1960, with William J. Corbett.

Major Reports and Publications (continued)

40. BETWEEN EARTH AND SPACE, The Macmillan Company, New York, N. Y., 1959.
41. "Tremendous Power of Lightning," Science Digest 45, 6, 27-32 (1959).
42. "Spectacles in the Skies," Science Digest 46, 2, 76-81 (1959).
43. "Adhesion Between Solid Particles and Solid Surfaces," Final Report on NIH Grant S-87, 1959, with others.
44. "Kaolin Dust Exposure Effects in Production Processing," Preliminary Report on NIH Grant RG-5931, 1969, with L. M. Petrie and R. L. McLean.
45. "A Study of the Alteration of Water Droplet Supercooling by Foreign Vapors," 7 reports on Contract AF 19(604)-4970, 1959-1960 with others.
46. "An Investigation of the Particle—Collecting Capability of Thermal Precipitation at Simulated High-Altitude Conditions," Annual Report on Contract AT(40-1)-2568, 1959-1960, with others.
47. "Source Control by Filtration," Chapter 29 in AIR POLLUTION, Volume II, Academic Press, 1961, with J. M. DallaValle (Arthur C. Stern, editor).
48. "Aerosols" and "Electrostatic Precipitation," sections in ENCYCLOPAEDIC DICTIONARY OF PHYSICS, Volumes 1 and 2, respectively, Pergamon Press, 1961.
49. "Interaction of Submicron Smog Particles and Vapors," Annual and Final Reports on NIH Grant S-106, 1960-1962, with others.
50. "Adhesion of Solid Particles to Solid Surfaces," Archives of Environmental Health 1, 1-9 (1960), with Margaret C. Kordecki.
51. "Our Changing Environment," Landscape, Spring Issue, 28-33 (1960).
52. "The Apparent Viscosity of Gas-Solid Fluidized Systems," J. of Chem. & Engr. Data 5, 430-432 (1960), with F. Liu.
53. Russian, French, Italian, and Indian language editions of BETWEEN EARTH AND SPACE.
54. "Aqua Regia Off-Gases by Infrared Spectrophotometry," Applied Spectroscopy 15, 180-181 (1961), with Margaret C. Kordecki.
55. "An Investigation of Thermal Force with Particular Reference to Materials of High Thermal Conductivity," Final Report on NSF Grant G7051, 1961, with others.
56. "Pigment Particle Size Separation," 5 reports on NASA Contract No. NAS8-848, 1961-62, with others.
57. "Particle Classifier Employing Adhesion Principle," Final Report on NIH Grant No. AP-120, 1962, with others.
58. "Centrifugal Separation and Classification," Final Report on NIH Grant No. AP-127, 1962, with others.
59. "Inhibition of 'Spontaneous' Nucleation," Tellus XIV, 326-327 (1962).
60. DE LEVENDE DAMPKRING (Dutch translation of BETWEEN EARTH AND SPACE), Bibliotheek voor Algemene Ontwikkeling Bussum, Antwerpen, 1961, translated by J. Van Diggelen.
61. "Effects of High Density Ionizing Radiation on Colloidal Systems and Suspensions," 18 reports on AEC Contract No. AT(38-1)-202, 1962-1963, with others.
62. "Hydrogenation of Pulverized Coal in a Plasma Jet," Final Report on Dept. of Interior Contract No. 14-01-001-228, 1962-1963, with others.
63. "Heat Transfer to a Gas Containing a Cloud of Particles," 2 reports on NASA Grant NsG-273-62, 1962-1963, with others.
64. "Photophoresis as Related to Meteorological Phenomena," 2 reports on NSF Grant No. G-19273, 1962-1963, with others.
65. "Particulate Size Analyzer Using Ion Counter Principle," Annual Report on NIH Grant No. OH-00129-02, 1963, with F. K. Hurd and W. P. Hendrix.

Major Reports and Publications (continued)

66. Abridged Edition of BETWEEN EARTH AND SPACE for U.S. Information Agency, Pocket Books, Inc., New York, 1963.
67. "Aerosol Size Distribution in the Submicron Range from Ion Mobility Measurements," Proc. Am. Assoc. Contamination Control 1, 1-15, (Oct. 1962), with J. Burson.
68. "Particle Size Classifier for the Subsieve Range," Rev. Sci. Inst. 34, 1023-1025 (1963), with others.
69. "Particle Size Classification by Adhesion," Nature 200, No. 4904, 360-361 (1963).
70. "Light Boundary Effect in Photophoresis," Nature 200, No. 4904, 352 (1963).
71. "Thermal Conductivities of Aluminum and Zinc Powder Suspensions," J. Chem. & Eng. Data 9, No. 1, 71-74 (1964).
72. "The Photophoretic Force," J. Colloid Sci. 19, No. 1, 50-60 (1964).
73. "Thermal Precipitation at Reduced Gas Pressures," J. Colloid Sci. 19, 571-577 (1964).
74. "Photophoretic Effects in the Stratosphere," J. Atmospheric Sciences 21, No. 5, 475-478 (1964).
75. "Thermal Precipitator," Rev. Scientific Instruments 35, No. 10, 1373-1374 (1964).
76. "Thermal Precipitation and Particle Conductivity," J. Colloid & Interface Science 22, 107-16 (1966).
77. PARTICULATE TECHNOLOGY, The Macmillan Co., New York, 1966.
78. Pigment Particle Size Separation, National Aeronautics and Space Administration Report, CR-78, July 1964, with W. J. Corbett.
79. Heat Transfer to a Gas Containing a Cloud of Particles, National Aeronautics and Space Administration Report, CR-54441, July 1965, with J. A. McAlister, E. Y.H. Keng.
80. Heat Transfer to a Gas Containing a Cloud of Particles, National Aeronautics and Space Administration Report, CR-325, November 1965, with J. A. McAlister, E. Y.H. Keng.
81. "Specific Surface Area by Low-Pressure Permeametry," Analytical Chem. 39, 834-6 (1967).
82. "Particle Dynamics in Centrifugal Fields," Powder Technology 1, 305-316 (1968) with others.
83. "A Method for Predicting the Properties of Supersaturated Solutions of the Alkali Chlorides," J. Chem. & Eng. Data 13, 49-53 (1968) with A. F. Hidalgo.
84. "Aerosol Research in Chemical Engineering at Georgia Tech," Air Pollution Control Association Journal 17, 590-592, Sept. 1967, with others.
85. Investigation of Radiant Heat Transfer to Particle-Seeded Gases for Application to Nuclear Rocket Engine Design, CR-953, Washington, D.C., November 1967, with E. Y.H. Keng.
86. "Homogeneous Nucleation of Sodium Chloride Solutions," Industrial and Engineering Chemistry Fundamentals Quarterly 7, 79-83 (1968) with A. F. Hidalgo.
87. "Particle Size and the Rate of Radiant Heat Transfer to Gas-Suspended Particles," Powder Technology 1, 323-327 (1968).
88. "Source Control by Filtration," Chapter 44, in AIR POLLUTION, Volume III (Arthur C. Stern, editor), Academic Press, New York, 1968, with K. Iinoya.

Major Reports and Publications (continued)

89. The Influence of Electrostatic Effects on the Dispersion of Organic Powders, Final Report, Contract DA18-035-AMC-1058(A), U. S. Army Edgewood Arsenal Chemical Research and Development Laboratories, August 1968, with others.
90. FINE PARTICLE MEASUREMENTS (Japanese Translation), 1968, with J. M. Dallavalle.
91. "Size Reduction", ENCYCLOPEDIA OF CHEMICAL TECHNOLOGY, Vol. 18, pp. 324-65, John Wiley & Sons, Inc., New York, 1969.
92. "Radiant Heat Transfer to Absorbing Fluid Media", J. Chem. Eng. Japan 3, 171-6 (1970), with E.Y.H. Keng.
93. "Automatic Sedimentation Size Analysis Instrument", PARTICLE SIZE ANALYSIS 1970, Society for Analytical Chemistry, 1972, London, pp. 133-46, with W. P. Hendrix.
94. "A Completely Automated Computer Operated Gaseous Sorption Analyzer", presented at the 23rd Pittsburgh Conference on Analytical Chemistry and Applied Spectroscopy, March 6-10, 1972, with others.
95. "Aerosols Produced by X-Rays", J. Coll. and Interface Sci. 39, 94-102 1972, with E. Keng.
96. "Permeametry in the Knudsen-Flow Regime", Anal. Chem. 44, 1534-7 (1972), with J. F. Brock.
97. "Homogeneous Nucleation in Contaminated Atmospheres", Final Report, Project B-364, Contract No. AP 00816, Environmental Protection Agency, 1972 with others.
98. "Formation of Nonvolatile Particulates from Organic Vapors", Final Report, Project B-358, Contract No. OH 00329, Public Health Service, 1972, with others.
99. "Solid/Gas Aerosols", THE ENCYCLOPEDIA OF CHEMISTRY, 3rd Ed. pp. 28-30, Van Nostrand Reinhold Co., New York, 1973.
100. "Aerocolloid Formation from Semisolid Materials Exposed to Sunlight", Archives of Environmental Contamination & Toxicology 9, 356-60, (1973), with E.Y.H. Keng.
101. "The Influence of Diffusion on Sedimentational Particle Size Analysis", to be published in Powder Technology, with D.W. Moore.
102. "Filtration", Chapter 37, to be published in AIR POLLUTION, 3rd Ed., Academic Press, Inc., New York, with K. Iinoya.
103. "Characterization of Pigments by Gravity Sedimentation Techniques", to be published in PIGMENT HANDBOOK, Wiley-Interscience, New York, with J.W.P. Smithwick.
104. "Characterization of Pigments by Permeability Techniques", to be published in PIGMENT HANDBOOK, Wiley-Interscience, New York, with R.W. Tyree.
105. "Converting Particle Surface Area Data to a Mean Particle Size", to be published in PIGMENT HANDBOOK, Wiley-Interscience, New York.
106. "Surface Area Measurement", to be published in TREATISE ON ANALYTICAL CHEMISTRY, Interscience Publishers, New York.
107. "Particle Size Measurement" to be published in TREATISE ON ANALYTICAL CHEMISTRY, Interscience Publishers, New York.

Major Reports and Publications (continued)

108. "Pore Volume Measurement" to be published in TREATISE ON ANALYTICAL CHEMISTRY, Interscience Publishers, New York.
109. FILTRATION--PRINCIPLES AND PRACTICES, as editor, to be published by Marcel Dekker, Inc., New York.

Patents

1. "Electrical Resistance Paint Capable of Forming a Heating Film," U.S. Patent No. 2,883,307 (1959).
2. "Method and Apparatus for Measuring Electrical Charge on Aerosol Particles," U. S. Patent No. 2,909,960 (1959), with others.
3. "Cascade Impactor for Sampling Smokes, Dusts and Fume," U. S. Patent No. 2,947,164 (1960).
4. "Continuous Thermal Precipitator," U. S. Patent No. 2,947,382 (1960).
5. "Method and Apparatus for Obtaining Data for Determining Surface Area and Pore Volume," U. S. Patent No. 3,262,319 (1966).
6. "Specimen Mounting Device for Porosity Determination Apparatus," U. S. Patent No. 3,348,395 (1967).
7. "Pressure Gauge," U. S. Patent No. 3,368,407 (1968).
8. "Continuous Thermal Precipitator," U. S. Patent No. 3,458,974 (1969).
9. "Method and Apparatus for Measuring Angle of Contact between Liquids and Solids", U. S. Patent No. 3,525,255 (1970).
10. "A Method of and Apparatus for the Measurement of Surface Area", British Patent No. 1, 243, 143 (1971).
11. "Sample Extractor", U. S. Patent No. 3, 584,765, June 15, 1971.
12. "Apparatus for Collecting Particulate Matter from a Gas Stream", British Patent No. 1, 228, 318, April 15, 1971.

Georgia Institute of Technology

BIOGRAPHICAL SKETCH

POULOS, NICK E., -- Associate Chief, High Temperature Materials Division, Engineering Experiment Station

Education

B.Cer.E., Georgia Institute of Technology	1952
M.S. in Cer.E., Georgia Institute of Technology	1953
LL.B., Woodrow Wilson Law School	1955

Employment History

U.S. Army Air Force, Flight Engineer	1943-1946
The Coca-Cola Company, Student Engineer	1951-1952
Georgia Institute of Technology	
Research Assistant and Assistant Research Engineer	1953-1957
Research Engineer	1957-1965
Senior Research Engineer	1965-1966
Principal Research Engineer	1966-Present
Associate Chief, High Temperature Materials Division	1968-Present

Experience Summary: Active in ceramic research since 1953. Worked in the design and development of glass containers for increased service life. Director of numerous research projects on clay minerals, high temperature resistant materials and coatings. Research on clay minerals included paper coating clays and clays in refractories. The high temperature resistant materials research included the study of thermite reactions for forming cermets, development of slip-cast fused silica for use as heat treating forming dies and fixtures, radomes, permanent foundry molds, and thermal protection of reentry bodies. Coating research work was with arc-plasma-jet and flame sprayed coatings. Directed work on ceramic and ceramic-metal systems. Also directed studies on inorganic fiber felted systems and their application as high temperature resistant structures. General Coordinator, U. S. Air Force/Georgia Tech Symposium on Electromagnetic Windows, 1966 and in 1968, and General Co-ordinator, Tenth Symposium on Electromagnetic Windows, July 1970.

Current Fields of Interest

High-temperature resistant materials; ceramic-metal systems; thermal insulative materials for hypervelocity vehicles; new ceramic processes and products development; and R&D management.

Major Reports and Publications

1. "A Method for Studying the Resistance of Enamels to Abrasion by Rapidly Moving Particles Suspended in High-Temperature Flames," American Ceramic Society Bulletin (October 1952)
2. "An Automatic Device for Electrodialysis," presented at the 58th Annual Meeting of the American Ceramic Society, Cincinnati, Ohio, 1955
3. "The Study and Development of New High-Temperature Materials and Coatings," Reports on Contract NOrd 15701, 1956-1962, with others
4. Development of Monolithic Ceramics and Heterogeneous Ceramic-Metal Bodies for Aerodynamic Applications at High Velocities and Temperatures," Reports on Contract DA 01-009 ORD-548, 1957-1959, Contract DA 01-009 ORD-777, 1959-1960, and Contract NAS-8, 1960, with others
5. "Clay Mineral Research," Research Engineer 13, No. 5, 9 (December 1958)
6. "Ceramic Nose Cones," Research Engineer 13, No. 5, 10-11 (December 1958)
7. "Cermets from Thermite Reactions," Journal of the American Ceramic Society 42, 40-49 (1959) with others
8. "The Relationship of Structure of Georgia Kaolin to its Viscosity," Bulletin 23, Engineering Experiment Station, Georgia Institute of Technology, 1959
9. "Fused Silica: The Cinderella Ceramic," Research Engineer 15, No. 1, 7-9 (February 1960)
10. "Man-Made Meteor-The Nose Cone," Research Engineer 15, No. 1, 15,16, (February 1960)
11. "Ceramic Tooling," Research Engineer 15, No. 1, 20-21 (February 1960)
12. "The Use of Thermite Reactions to Produce Refractory Cermets," Ceramic Age 75, 39-45 (1960), with others
13. "Ceramic Tooling and Honeycomb Brazing Fixtures for Supersonic Aircraft Production," American Ceramic Society Bulletin 39, No. 12, 740-742, 747-748 (December 1960)
14. "Fused Silica Refractories," 8th International Ceramic Congress, Det Berlingske Bogtrykkery A/S, Copenhagen, Denmark, 213-222, May 1962, with others
15. "Slip-Cast Metal Fiber Reinforced Ceramics," American Ceramic Society Bulletin 41, No. 11, 778-780 (November 1962), with others
16. "Fused Silica-Hydrated Cements for Thermal Protection Systems," American Ceramic Society Bulletin 41, No. 12, 812-815 (December 1962), with others
17. "Ceramic Systems for Missile Structural Applications," Reports on Contract NOw-63-0143-d, 1962-1966, with others
18. "Design and Development of an EM Window for Air Lift Reentry Vehicles," Reports on Contract No. AF 33(657)-11504, 1963-1966, with others
19. "Spray-On Refractory Coatings System Considerations," presented at the National AIME Meeting, Pyro-Metallurgical Program, Dallas, Texas, February 1963, with others
20. "Slip-Cast Fused Silica," Special Report No. 43, Published in 1964 by Engineering Experiment Station, Georgia Institute of Technology, with others

Major Reports and Publications (continued)

21. "Slip Casting Large Fused Silica Radomes," Proceedings of the OSU-RTD Symposium on Electromagnetic Windows (Vol. III) Session V, Paper D, 2-4 June 1964, with others
22. "Fused Silica for Reentry Radomes," Proceedings of the OSU-RTD Symposium on Electromagnetic Windows (Vol. III) Session VI, Paper B, 2-4 June 1964, with others
23. "Design and Development of an Electromagnetic Window for Air Lift Reentry Vehicles," Technical Report AFAL-TR-65-86, May 1965, with others
24. "Fibrous Ceramic Structures," presented at American Ceramic Society Symposium on "High Temperature Fibers and Fibrous Composites," Philadelphia, Pennsylvania, May 1965, with others
25. "Design and Development of an Electromagnetic Window for Air Lift Reentry Vehicles," Technical Report AFAL-TR-66-34, March 1966, with others
26. "Design/Development of Slip-Cast Fused Silica Nose Cap for Trailblazer III Vehicle," Proceedings of the U.S. Air Force-Georgia Tech Symposium on Electromagnetic Windows, Session I, 1-3 June 1966, with others
27. "Thermal Testing of Slip-Cast Fused Silica Radomes," Proceedings of the U.S. Air Force-Georgia Tech Symposium on Electromagnetic Windows, Session VI, 1-3 June 1966, with others
28. "A Feasibility Study on the Fabrication of Integrated Radome Antennas," Proceedings of the U.S. Air Force-Georgia Tech Symposium on Electromagnetic Windows, Vol. IV, 1-3 June 1966, with others
29. "Development of Lightweight Broadband Radomes from Slip-Cast Fused Silica," Technical Report AFAL-TR-67-56, April 1967, with others
30. "High-Strength, Broadband, Lightweight Silicon Oxide Radome Techniques," Reports on Contract F33615-67-C-1594, 1967-Present, with others
31. "Ceramic Systems for Missile Structural Applications," Reports on Contract N00017-67-C-0053, 1966-Present, with others
32. "Proceedings of the Tenth Symposium on Electromagnetic Windows," 29-31 July 1970, Co-Editor
33. "Historical Development of Radomes," Chapter 1 of RADOME ENGINEERING HANDBOOK - DESIGN AND PRINCIPLES (J. D. Walton, Jr., Editor) Marcel Dekker, Inc., New York, 1970

Georgia Institute of Technology

BIOGRAPHICAL SKETCH

SALES, ARTHUR T. -- Research Engineer, Evaluation and Analysis Branch, High Temperature Materials Division, Engineering Experiment Station

Education

B.Cer.E., Georgia Institute of Technology	1960

Employment History

Allison Division, General Motors Corporation	
Summer Employee	1956 & 1959
Allis-Chalmers Manufacturing Company	
Engineering Scientist	1962-1963
Ceramic Engineer	1962-1963
Georgia Institute of Technology	
Student Assistant	1957-1959
Research Assistant	1959-1962 & 1964-1965
Assistant Research Engineer	1965-1966
Research Engineer	1966-Present

Experience Summary: Assigned to the Electronics and Parts Test Department and Metallurgical Research Department at Allison Division as a student employee to design test fixtures, process arc-plasma spray metal powders, maintain high temperature heating equipment. In Applied Research Section of Allis-Chalmers, was responsible for the investigation of techniques to produce various nitrides, borides, sulfides, carbides, phosphides, and intermetallics; laboratory production of catalysts and catalytic reinforced porous metallic electrodes for fuel cells; the study of continuous induction furnace sintering for the production of nitrides; and protective coating application by porcelain enamel or flame, wire, or arc-plasma spray processes. Reassignment to New Products Department of Allis-Chalmers involved the development, production, quality control, and sale of inorganic compounds and the job shop deposition of organic and inorganic protective coatings. Work at Georgia Tech includes flame and arc-plasma spray deposition of refractory and abrasion resistant materials and the physical property evaluation of the resultant coatings, kaolin clay property determinations, the fabrication of investment casting foundry molds, evaluation of porcelain enamels on quality steel, environmental testing of reentry vehicles, fiber and single crystal whisker reinforced materials, filament wound radomes and attachment systems, fabrication of radomes and electromagnetic windows, fiberglas reinforced plastics for high tensile load applications, development and evaluation of high temperature inorganic filament wound systems, applied research on the rain erosion protection of missile and aircraft structural components, and evaluation and analysis testing of ceramic materials.

Current Fields of Interest

Development of supersonic rain erosion resistant coating materials; improved methods of testing ceramic materials; organic and/or inorganic filament wound systems; arc-plasma sprayed refractory and abrasion resistant coatings; and the refractory hard metal compounds, alloys, and intermetallics; evaluation and analysis testing.

Major Reports and Publications

1. "Investigation of High Temperature Resistant Materials," Technical Reports, Naval BuOrd Contract NOrd-15701, 1960, coauthor
2. "Fused Silica Rocket Nozzles," Technical Reports, Naval BuOrd Contract NOrd-18564, 1960-1961, coauthor
3. "Investigation of Clay Properties," Final Summary Report prepared for the Refractories Division of the Babcock and Wilcox Company, April 1962, coauthor
4. "A Study of the Interfacial Reactions in Enameling Magnesium Metal," Bachelor's Requirements, Georgia Institute of Technology, 1959
5. "Improving the Mechanical Properties of Slip-Cast Fused Silica by Fibrous Reinforcements," Final Report on Sandia Corporation Contract 16-2092 1965, coauthor
6. "Design and Development of an Electromagnetic Window for Air Lift Reentry Vehicles," Technical Report AFAL-TR-66-34, Air Force Avionics Laboratory, 1966, coauthor
7. "Filament Wound Silica Radome Techniques," Technical Reports, Air Force Avionics Laboratory Contract AF-33(615)-3330, 1966, coauthor
8. "Slip-Cast Fused Silica 'Y' Payload Radomes and EM Windows," Final Technical Report on Southern Electronics Engineering Company, P. O. Nos. 2593 and 2594, 1967
9. "Exploratory Development of Supersonic Rain Erosion Resistant Coating Materials," a paper presented at the U.S. Air Force-Georgia Tech Symposium on Electromagnetic Windows, June 1968, coauthor
10. "Exploratory Development of Supersonic Rain Erosion Resistant Coating Materials," Technical Reports, Air Force Materials Laboratory, Contract F33615-67-C-1439, 1968, coauthor
11. "Ceramic Systems for Missile Structural Applications," Technical Report, Naval Ordnance Systems Command, Contract N00017-67-C-0053, 1968, coauthor
12. "Establishment of Optimal Arc Plasma Parameters for the Production of Impart Resistant Coatings," a paper presented at the Fall Meeting of the Ceramic-Metal Systems Division of the American Ceramic Society, September 1969, coauthor
13. "Supersonic Rain Erosion Resistant Coating Materials," Technical Reports, Air Force Materials Laboratory, Contract F33615-69-C-1179, 1969, coauthor

Georgia Institute of Technology

BIOGRAPHICAL SKETCH

WALTON, JESSE D., Jr. -- Chief, High Temperature Materials Division, Engineering Experiment Station

Education

B.Cer.E., Georgia Institute of Technology 1950

Employment History

U.S. Navy	1943-1946
Ferro Corporation, Research Engineer	1950-1952
Georgia Institute of Technology	
Research Assistant and Assistant Research Engineer	1952-1955
Research Engineer	1955-1959
Special Research Engineer	1959-1965
Principal Research Engineer	1965-Present
Chief, High Temperature Materials Division	1968-Present

Experience Summary: Performed original research in the field of porcelain enameling at the Ferro Corporation. Actively engaged in ceramics research and development at Georgia Tech since 1952. Contributions in the study of stresses between enamel and metal, and for differential thermal analysis. Work of ceramic materials includes study of thermite reactions as a means for producing cermets, development of slip-cast fused silica for such uses as permanent foundry molds, heat treating dies and fixtures, telescope reflectors, radomes, and thermal protection of reentry bodies. Research in field of coatings includes vapor deposition and diffusion type intermetallic coatings, electrical insulation for wire, and arc-plasma-jet and flame sprayed coatings. Director of numerous projects on development and study of ceramic and ceramic-metal systems. Chairman, Ceramic-Metal Systems Division, American Ceramic Society 1965-66. Fellow of the American Ceramic Society.

Committees and Panels

General Chairman, U.S. Air Force/Georgia Tech Symposium on Electromagnetic Windows, 1966 and 1968; General Chairman, Tenth Symposium on Electromagnetic Windows, 1970; Member, Materials Advisory Board of the National Academy of Sciences, Ad Hoc Committee on Ceramic Processing; Chairman, Panel on Evaluation, Ad Hoc Committee on Ceramic Processing; Member ASTM Committee F-4, Surgical Implant Materials; Member ASTM Committee G-2, Erosion by Cavitation of Impingement; Member ASTM Committee C-22, Ceramic Coatings; Participant in Advisory Group for Aerospace Research and Development of NATO Specialists Conference on Design in Brittle Materials, London, England, 1967; Participant USNSF-Japan Seminar on Characterization of Ceramic Materials, Tokyo, Japan, 1969.

Current Fields of Interest

High-temperature ceramic, ceramic-metal, and intermetallic materials; arc-sprayed, flame-sprayed, vapor deposited, and diffusion-type coatings; design of special environmental equipment for the evaluation of high-temperature materials. Radomes for hypersonic and reentry vehicles. Evaluation of ceramic materials. Ceramic materials for surgical implants.

Major Reports and Publications

1. "Determination of Opacity by Means of a Translucency Meter," Am. Cer. Soc. Bulletin 29, No. 8, 282-285 (August 1950)
2. "Determination of Strains Between Enamel and Iron by Means of Split Rings," Journal of American Ceramic Society, 36, No. 10, 335, 341 (October 1953) with others
3. "Study of Strains Between Enamel and Iron as Related to the Physical Properties of Each," Journal of American Ceramic Society 37, No. 3, 153-160 (March 1954)
4. "Apparatus for Automatically Recording Strains Between Enamel and Metal," Journal of American Ceramic Society 38, No. 3, 114-118 (March 1955)
5. "New Method of Preparing Clay Samples for Differential Thermal Analysis," Journal of American Ceramic Society 38, No. 12, 432-443 (December 1955)
6. "Cermets from Thermite Reactions," Journal of American Ceramic Society 42, No. 1, 40-49 (January 1959), with others
7. "Experimental Application of Arc and Flame Sprayed Coatings," presented at the First Aerospace Finishing Symposium, Fort Worth, Texas, 7-9 December 1959, with others
8. "Ceramics for High Temperature Electrical Applications," presented at the Second National Conference on the Application of Electrical Insulation, Washington, D. C., 8-11 December 1959, with others
9. "The Use of Thermite Reactions to Produce Refractory Cermets," Ceramic Age 75, No. 6, 39-45 (June 1960), with others
10. "Materials Problems Associated with Uncooled Rocket Nozzles," Corrosion 16, No. 8, 371t-374t (August 1960), with others
11. "Fused Silica for Missile Components," Part I Ceramic Age 76, No. 2, 33-38 (August 1960); Part II Ceramic Age 76, No. 3 (23-28 September 1960)
12. "Ceramic Tooling and Honeycomb Brazing Fixtures for Supersonic Aircraft Production," American Ceramic Society Bulletin 39, No. 12, 740-742, 747-748 (December 1960), with others
13. "Present and Future Problem Areas for High Temperature Inorganic Coatings," American Ceramic Society Bulletin 40, No. 3, 136-141 (March 1961)
14. "Evaluation of Ceramic Materials Under Thermal Shock Conditions," Mechanical Properties of Engineering Ceramics, Interscience Publishers, New York, London, 149-171, 1961, with others
15. "Fused Silica Ceramics," Part I Ceramic Age 77, No. 5, 52-58 (May 1961); Part II Ceramic Age 77, No. 6, 53-58 (June 1961); Part III Ceramic Age 78, No. 1, 38-45 (July 1961)
16. "Fused Silica Refractories," 8th International Ceramic Congress, Det Berlingske Bogtrykkery A/S, Copenhagen, Denmark, 213-222, May 1962, with others
17. "Slip-Cast Fused Silica Radomes," Proceedings of the ASD-OSU Symposium on Electromagnetic Windows, Technical Documentary Report No. ASD-TDR-62-676 (Vol. I), July 1962, with others

Major Reports and Publications (continued)

18. "Slip-Cast Metal Fiber Reinforced Ceramics," American Ceramic Society Bulletin 41, No. 11, 778-780 (November 1962), with others
19. "Fused Silica-Hydrated Cements for Thermal Protection Systems," American Ceramic Society Bulletin 41, No. 12, 812-815 (December 1962) with others
20. "Spray-On Refractory Coatings System Considerations," presented at the National AIME Meeting, Pyro-Metallurgical Program, Dallas, Texas, February 1963, with others
21. "Slip-Cast Fused Silica," ML-TDR-64-195, October 1964, with others
22. "Slip Casting Large Fused Silica Radomes," Proceedings of the OSU-RTD Symposium on Electromagnetic Windows, (Vol. III) Session V, Paper D, 2-4 June 1964, with others
23. "Fused Silica for Reentry Radomes," Proceedings of the OSU-RTD Symposium on Electromagnetic Windows, (Vol. III) Session VI, Paper B, 2-4 June 1964, with others
24. "Slip-Cast Ceramic-Ceramic Fiber Composites," presented at the American Ceramic Society Symposium on "High Temperature Fibers and Fibrous Composites," Philadelphia, Pa., May 1965, with others
25. "Metal-Fiber Reinforced Ceramics," Fiber Composite Materials, American Society for Metals, Metals Park, Ohio, Chapter 10, 1965
26. "Properties of Ceramic Composites Containing Fibrous Reinforcements," PROCEEDINGS OF THE CONFERENCE ON NUCLEAR APPLICATIONS OF NON-FISSIONABLE CERAMICS (A. Boltax and J. H. Handwerk, eds.) 113-129, American Nuclear Society, Inc., Hinsdale, Illinois, 1966, with others
27. "Felted Ceramics," American Ceramic Society Bulletin 45, No. 6, June 1966
28. "A Hydrosonic Rain Erosion Test Program," Proceedings of the U.S. Air Force-Georgia Tech Symposium on Electromagnetic Windows, Atlanta, Georgia, 1-3 June 1966, with others
29. "Techniques for Airborne Radome Design," AFAL-TR-66-391, Volume II, December 1966, Editor-in-Chief
30. "Rain Erosion of Ceramics at High Mach Numbers," Proceedings of the 2nd Conference on Rain Erosion, Meersburg, West Germany, 16-18 August 1967, with others
31. "Rain Erosion at High Mach Numbers," International Conference on Electromagnetic Windows, Paris, France, 6-8 September 1967, with others
32. "Ceramic Processing," Publication 1576 National Academy of Sciences, Washington, D. C., 1968, Chapter 5, Report of the Panel on Evaluation, with others
33. "Sintered Fused Silica," Interceram, Freiburg, Germany, Vol. 17, No. 2, 121-122, 133, June 1968
34. "Evaluation of Ceramics, the Significance of Testing," Proceedings of the First U.S.-Japan Seminar on Basic Science of Ceramics, "Characterization of Ceramic Materials," Tokyo, Japan, 24 February - 1 March 1969

Major Reports and Publications (concluded)

35. "Mechanical Properties of Oxide Ceramics," Meeting of ASTM Committee F-4 on Surgical Implant Materials, Memphis, Tenn., 20 November 1969
36. "Supersonic Rain Erosion Resistant Ceramic Coatings," Proceedings of the Air Force Symposium, Miami, Florida, 18-22 May 1970
37. "Evaluation of Ceramic Coatings for Rain Erosion Protection," Proceedings of the U. S. Air Force-Georgia Tech Symposium on Electromagnetic Windows, Atlanta, Georgia 29-30 July 1970, with others
38. Proceedings of the Tenth Symposium on Electromagnetic Windows, 29-31 July 1970, Co-Editor
39. "Evaluation of Ceramic Coatings for Rain Erosion Protection," Proceedings of the Third International Conference on Rain Erosion and Associated Phenomena, Elvetham Hall, England 11-13 August 1970, with others
40. RADOME ENGINEERING HANDBOOK - DESIGN AND PRINCIPLES, Marcel Dekker, Inc., New York, 1970, Editor
41. "The State of Technology of Ceramic Radomes, Their Use and Possibilities for the Future," Proceedings of the Second International Conference on Electromagnetic Windows, Volume II, Paris, France, September 8-10, 1971